MACROALGAE IN THE YARRA RIVER BASIN: FLORA AND DISTRIBUTION

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Forty three species and 13 "vegetative groupings" of macroscopically visible, attached algae are described from flowing water in the Yarra River basin near Melbourne, south-eastern Australia. Species and subgeneric vegetative groups from the Rhodophyta (18%), Chlorophyta (55%), Chrysophyta (13%) and Cyanophyta (= Cyanobacteria; 14%) are represented. This first algal flora for the region includes keys, descriptions and habitat notes for all species described. Stream habitats are classified into 11 macroalgal communities, ranging from the *Cladophora/Stigeoclonium* community in eutrophic, alkaline, hard urban creeks, to the batrachospermaceous communities in oligotrophic, acidic mountain streams. The "potential" flora in each habitat depends mainly on temperature, pH, hardness and total nutrients, whereas the "expressed" biomass at any time depends on seasonal variations in temperature and light, and on the periodicity and severity of floods. The results of the Yarra River basin survey are generally similar to those of overseas studies, although there are some differences in species composition.

CONTENTS

CATALOGUING and classifying stream communities of macroscopic algae in relation to physical and chemical attributes of waterways have been carried out in many river basins of Europe and North America (Blum 1959, Whitton 1984). In Britain, biological indicator species and communities are frequently used to assess stream pollution (Connor 1985). Major algal blooms resulting in significant degradation of waterways in New Zealand consist primarily of filamentous macroalgae (Biggs 1985). Such blooms are unattractive aesthetically, reduce the value of rivers for fishing and swimming, degrade water quality by causing large diurnal fluctuations in pH, and clog water-intake piping (Biggs 1985).

The terms "macroalgae" (macroscopically visible, usually filamentous, algae) or "mesophytes" (*sensu* Goldman & Horne 1983) are useful labels for the group of freshwater plants dealt with in the present survey. Such organisms classically have been termed the "Confervae", and in the early days of Linnaean botany were regarded as "a natural family" (Dillwyn 1809: 50). Although the "Confervae" is now known to include representatives of several divisions with a diverse array of life histories and biochemistries, it provides a convenient ecological unit of study. It includes algae distinct from the phytoplankton and microalgae, which require different methods of collection and preservation. In eighteenth century England, the Confervae were described as the "opprobrium of botany" (Smith 1791: 34). Such freshwater algae in Australia today fare little better in the regard of most scientists.

Prior to the survey of freshwater Rhodophyta by Entwisle & Kraft (1984) , over 60 years had elapsed since any significant records of freshwater macroalgae in Victoria had appeared in scientific journals. Most early publications (e.g. Watts 1865, 1887; Hardy 1905, 1906) dealt only incidentally with the algae of rivers, and then only in the form of checklists of species. The inability to verify earlier Victorian records, due to inadequate preservation or description of critical taxonomic characters, or lack of any voucher material, renders most of them suspect or worthless (Entwisle 1989b). Compared with the information currently available on the invertebrate and vertebrate fauna of inland waters (Bayly & Williams 1973), our understanding of the algae, particularly the macroalgae, is very poor.

Although most species of freshwater macroalgae are assumed to be cosmopolitan, there is no one source (or even combination of accessible sources) which can be used for identification of the Australian representatives. Since the 1960s there have been many taxonomic revisions of freshwater macroalgal groups (e.g. van den Hoek 1963 on *Cladophora*; Rippka et al. 1979 and Drouet 1981 on Cyanophyta; Cox & Bold 1966 and Simons et al. 1986 on *Stigeoclonium*) which have resulted in the renaming and synonymizing of many species. A critical evaluation of the morphological and habitat range of each taxon is also needed for each particular region; only the Rhodophyta (Entwisle & Kraft 1984) and *Vaucheria* (Entwisle 1988) have received any contemporary taxonomic treatment in Australia.

THE YARRA RIVER BASIN

The Yarra River is over 200 km long, with its headwaters in the Great Dividing Range at altitudes over 800 m above sea level, and its lower reaches in urban Melbourne. Its catchment of 1200 km^2 includes forestry, agricultural and urban land uses. The undisturbed highland tributaries are mostly soft, acidic and well-shaded, whereas those flowing through urban areas are hard, alkaline, and carry considerable nutrient loads (Victoria E.P.A. 1983). Turbidity is notoriously high in the Yarra River itself and in some of the major tributaries, but most smaller streams carry little particulate matter in normal flow. The substrata supporting macroalgae range from gravel and boulders (*sensu* Cummins 1962) in most riffle areas, to aquatic angiosperms.

Numerous studies have reported on various facets of the Yarra River basin, including geology (Jutson 1911, VandenBerg 1973, Rosengren et al. 1983), water quality (Scott & Furphy 1972, Consulting Environmental Engineers 1986, Victoria E.P.A. 1982, 1983) and invertebrates (Victoria R.W.C. 1985, Campbell et al. 1982), and there are also many unpublished data on water quality and quantity. The rivers and streams of the Yarra River basin supply Melbourne with drinking water, recreation facilities and waste drains (the objectives for water quality are outlined in State Environmental Protection Policy No. W-29, made an act of parliament in 1984). The adjacent habitats range from protected, pristine forests to the second-most densely populated urban region on the continent. The Yarra River basin, therefore, is an important region on which to base this first floral and ecological study of freshwater macroalgae in Australia.

METHODS

Sampling

Most algae collected were epilithic in riffles where the substratum receives sufficient light and the exchange of nutrients and wastes is adequate. Only plants forming macroscopically visible thalli attached to the substratum are included in the survey (the smaller Oedogoniaceae and Cyanophyta, for example, are excluded). Most collections were from depths of less than 0.5 m but intensive collecting in deeper water near Warburton and Warrandyte failed to produce any new records or to indicate major changes in floral composition at greater depths.

A total of 121 sites (Table 1, Fig. 1) were sampled at least twice, usually in spring and autumn during 1986-1988. The species were recorded as present/absent or by using a semi-qualitative measure of abundance (0 = absent, 1 = isolated plants, 2 = not common, 3 = common and easily observed). Most populations could be identified to species level or at least into vegetative groups on the basis of field material, but

Table 1. Sites sampled in the Yarra River basin.

Site No.	Stream Name & Locality	Universal Grid Ref. 55H-)	EPA Strata*
1	Bushy Creek, Elgar Road	CU342148	[7]
2	Diamond Creek, Lower Plenty	CU364217	[11]
3	Diamond Creek, Eltham North	CU370254	[11]
4	Diamond Creek, Diamond Creek	CU404327	[11]
5	Diamond Creek, Hurstbridge	CU404327	[11]
6	Arthurs Creek, Arthurs Creek	CU415388	[17]
7	Arthurs Creek, Strathewen	CU468427	[17]
8	Diamond Creek trib., St Andrews North	CU514419	[17]
9	Diamond Creek, Mittons Bridge	CU485385	[17]
10	Diamond Creek, St Andrews–Hurstbridge Rd	CU457364	[17]
11	Merri Creek, Heidelberg Road	CU242160	[6]
12	Darebin Creek, Heidelberg Road	CU271168	[8]
13	Merri Creek, Clifton Hill	CU241150	[6]
14	Sassafras Creek, Monbulk–Kallista Rd	CU585058	[22]
15	Sassafras Creek, Monbulk–Emerald Rd	CU603058	[22]
16	Yarra River, Kangaroo Ground–Warrandyte Rd	CU433218	[3]
17	Olinda Creek, Lilydale	CU555197	[19]
18	Olinda Creek trib., Mount Evelyn	CU565154	[19]
19	Olinda Creek, Sylvan	CU593138	[19]
20	McCrae Creek, Yellingbo	CU685138	[21]
21	Cockatoo Creek, Avonsleigh	CU678027	[22]
22	Cockatoo Creek trib., Avonsleigh	CU654009	[22]
23	Gardiners Creek, Ashwood	CU337090	[5]
24	Woori Yallock Creek, Warburton Highway	CU689188	[22]
25	Yarra River, Woori Yallock	CU707187	[20]
26	Yarra River, Warburton (East)	CU845206	[23]
27	Yarra River, O'Shannassy River junction	CU928242	[25]
28	McMahons Creek, McMahons Creek	CU966265	[26]
29	Five Mile Creek, Upper Yarra Reservoir Park	DU005298	—
30	Armstrong Creek, Reefton	CU985298	[26]
31	Starvation Creek, Warburton–Woods Point Rd	CU942249	[26]
32	Plenty River, Mernda	CU326365	[17]
33	Coranderrk Creek, Healesville	CU716283	[21]
34	Myrtle Creek, Healesville–Donna Buang Rd	CU774257	[24]
35	Yhan Creek trib., Donna Buang–Warburton Rd	CU842252	[24]
36	Cement Creek, Acheron Way–Donna Buang Rd	CU859253	[26]
37	Rocky Creek, Warburton	CU862218	[24]
38	Cumberland Creek trib., "The Big Culvert"	DU004424	[AR/O'S]
39	Cora-Lyn Creek, Cora-Lyn Falls	DU011423	[AR/O'S]

Table 1. Sites sampled in the Yarra River basin.

Site No.	Stream Name & Locality	Universal Grid Ref. 55H-)	EPA Strata*
40	Cumberland Creek, Cumberland Road	DU010425	[AR/O'S]
41	Watsons Creek, Eltham–Yarra Glen Rd	CU460292	[17]
42	Steels Creek, Steels Creek	CU568378	[21]
43	Dixons Creek, Melba Highway	CU595353	[21]
44	New Chum Creek, Toolangi–Healesville Rd	CU664375	[21]
45	Meyers Creek, Meyers Creek Reserve	CU693378	[21]
46	Watts River, Donnelly Weir Rd	CU705329	[21]
47	Watts River trib., Maroondah Dam Reserve	CU721328	[21]
48	Dixons Creek, Yarra Glen racecourse	CU575306	[21]
49	Shepherd Creek, Gembrook–Launching Place Rd	CU734016	[21]
50	Clark Creek, Gilwell Park Reserve	CU747024	[21]
51	McCrae Creek, Ewart Park Reserve	CU765061	[21]
52	Hoddles Creek, Gembrook–Launching Place Rd	CU759144	[22]
53	Little Yarra River, Powelltown	CU912082	[24]
54	Little Yarra R. trib., Little Yarra Rd	CU860095	—
55	Darebin Creek, Darebin Parklands (north end)	CU266176	[8]
56	Darebin Creek, Kingsbury	CU267232	[8]
57	Darebin Creek, Epping	CU264312	[8]
58	Merri Creek, Somerton	CU212314	[6]
59	Merri Creek, Preston	CU218206	[6]
60	Yarra River, Upper Yarra Catchment (Rd 21)	DU105250	[UPYAR]
61	Thompson Dam outflow, Upper Yarra Catchment	DU105252	—
62	Yarra River, Upper Yarra Catchment (Rd 13)	DU100252	[UPYAR]
63	Yarra River, Upper Yarra Catchment (Rd 12)	DU172235	[UPYAR]
64	Clear Creek, Upper Yarra Catchment (Rd 31)	DU068315	[UPYAR]
65	Walsh Creek, Upper Yarra Catchment (Rd 65)	DU051341	[UPYAR]
66	O'Shannassy River, above O'Shannasssy Dam	CU968316	[AR/O'S]
67	Picaninny Creek, Maroondah Catchment (Rd 1)	CU732284	[MAREC]
68	Slip Creek, Maroondah Catchment (Rd 1)	CU748283	[MAREC]
69	Blue Jacket Creek, Maroondah Catchment (Rd 1)	CU738282	[MAREC]
70	Coranderrk Creek, Maroondah Catchment (Rd 26)	CU819264	[MAROON]
71	Watts River, Maroondah Catchment (Rd 27)	CU830282	[MAROON]
72	Watts River, Maroondah Catchment (Rd 7)	CU845295	[MAROON]
73	Watts River, Maroondah Catchment (Rd 27)	CU845306	[MAROON]
74	Watts River, Maroondah Catchment (Rd 4)	CU786362	[MAROON]
75	Contentment Creek, Maroondah Catchment (Rd 13)	CU765360	[MAROON]
76	Watts River, Maroondah Catchment (Rd 32)	CU748347	[MAROON]
77	Donnellys Creek, Maroondah Catchment (Rd 20)	CU704358	[MAROON]
78	Yarra River, Warburton (West)	CU832204	[23]
79	Ythan Creek, Yarra River junction	CU833203	[24]
80	Big Pats Creek, Smyth Creek Rd	CU901196	[24]
81	Mississippi Creek, Lays Track	CU926191	[24]
82	Four Mile Creek, below La La Falls	CU857190	[24]
83	Yarra River, Millgrove	CU816205	[23]
84	Anderson Creek, Warrandyte Rd	CU422205	[13]
85	Mullum Mullum Creek, Warrandyte Rd	CU392200	[12]
86	Ruffys Creek, Parker St	CU345194	[10]
87	Koonung Creek, Thompsons Rd	CU309168	[7]
88	Little Yarra River, Yarra Junction	CU759181	[24]
89	Brushy Creek, Wonga Park	CU493224	[15]
90	Jumping Creek, Warrandyte–Wonga Park Rd	CU451215	[14]
91	Plenty River, Morang Sth–Yarrambat Rd	CU326313	[9]
92	Fir Tree Creek, Gladysdale	CU814127	[24]
93	Stringybark Creek, Lilydale–Healesville Rd	CU597255	—
94	Yarra River, Healesville–Lilydale Rd	CU667286	[20]
95	Yarra River, Tarrawarra	CU608307	[20]

Table 1. Sites sampled in the Yarra River basin.

Site No.	Stream Name & Locality	Universal Grid Ref. 55H-)	EPA Strata*
96	Yarra River, Yarra Glen	CU567304	[20]
97	Yarra River, Homestead Rd (Wonga Park)	CU488239	[3]
98	Yarra River, Fitzsimons Lane	CU357211	—
99	Yarra River, Banksia St	CU305189	[3]
100	Yarra River, Dights Falls	CU237147	[3]
101	Plenty River, Wittlesea	CU342470	[17]
102	Merri Creek, Merriang	CU245500	[17]
103	Morleys Creek trib., Black Spur 1 weir	CU787387	[MAREC]
104	Morleys Creek trib., Black Spur 2 weir	CU786385	[MAREC]
105	Morleys Creek trib., Black Spur 3 weir	CU785383	[MAREC]
106	Morleys Creek trib., Black Spur 4 weir	CU785375	[MAREC]
107	Ettersglen Creek, Monda 1 weir	CU745405	[MAREC]
108	Ettersglen Creek trib., Monda 2 weir	CU745404	[MAREC]
109	Ettersglen Creek trib., Monda 3 weir	CU745395	[MAREC]
110	Ettersglen Creek trib., Monda 4 weir	CU745393	[MAREC]
111	Ettersglen Creek trib., Ettercon 1 weir	CU762408	[MAREC]
112	Ettersglen Creek trib., Ettercon 2 weir	CU758404	[MAREC]
113	Contentment Creek trib., Ettercon 3 weir	CU758390	[MAREC]
114	Contentment Creek trib., Ettercon 4 weir	CU766400	[MAREC]
115	Myrtle Creek trib., Myrtle 1 weir	CU778401	[MAREC]
116	Myrtle Creek trib., Myrtle 2 weir	CU772392	[MAREC]
117	Running Creek, Masons Falls, Kinglake N.P.	CU445470	—
118	Plenty River, Greensborough	CU332255	—
119	Jacks Creek, Toorourrong Catchment	CU380515	—
120	Jacks Creek, "The Cascades" aqueduct	CU430540	—
121	Plenty River, Toorourrong Catchment	CU380540	—

*Numbers refer to strata delineated in Victoria, EPA (1982), except for AR/O'S = Upper Amstrong and O'Shannassy Catchments, MAREC = Maroondah experimental catchments, MAROON = Maroondah Catchment, UPYAR = Upper Yarra Catchment.

some (*Vaucheria*, *Stigeoclonium*) could only be referred to genera. Most of these latter collections were subsequently identified to species in culture. Physical and chemical data were taken from Melbourne & Metropolitan Board of Works (MMBW), Rural Water Commission (RWC) and Environmental Protection Authority (EPA) reports, and from unpublished sources. Temperature and general habitat characteristics were noted for all collections, whereas measurements of electrical conductance and pH were made selectively.

Culture conditions

Most species were grown in modified "Pickett-Heaps Diatom Media (DM)" (Table 2), although the isolation of representatives of the Rhodophyta and Cyanophyta was seldom attempted. The temperature was generally kept at 15°C but ranged from 13–20°C. Cool white fluorescent lights gave a photon irradiance of 50–100 $\mu mol/m^2/s$, and the day:night cycle was 16:8h.

Preservation and observation

Wet material was preserved initially in 5% commercial formalin. After permanent slides were made, a mixture of acetic acid/alcohol/glycerol was added so that final concentrations were commercial formalin 1: distilled water 10: ethanol 8: acetic acid 1: glycerol 1. This solution results in minimal plasmolysis and dissociation of cells in most algae, and the glycerol helps to prevent total dehydration of the specimen. The 30 mL screw top jars were sealed with "Nescofilm".

Chlorophyta were stained with 10% Lugol's Iodine and mounted in 50% "Karo" corn syrup (with 0.25% phenol), or in 10% glycerol (with more glycerol solution added following evaporation) and sealed with nail polish. Rhodophyta and Cyanophyta were stained with 1% Aniline

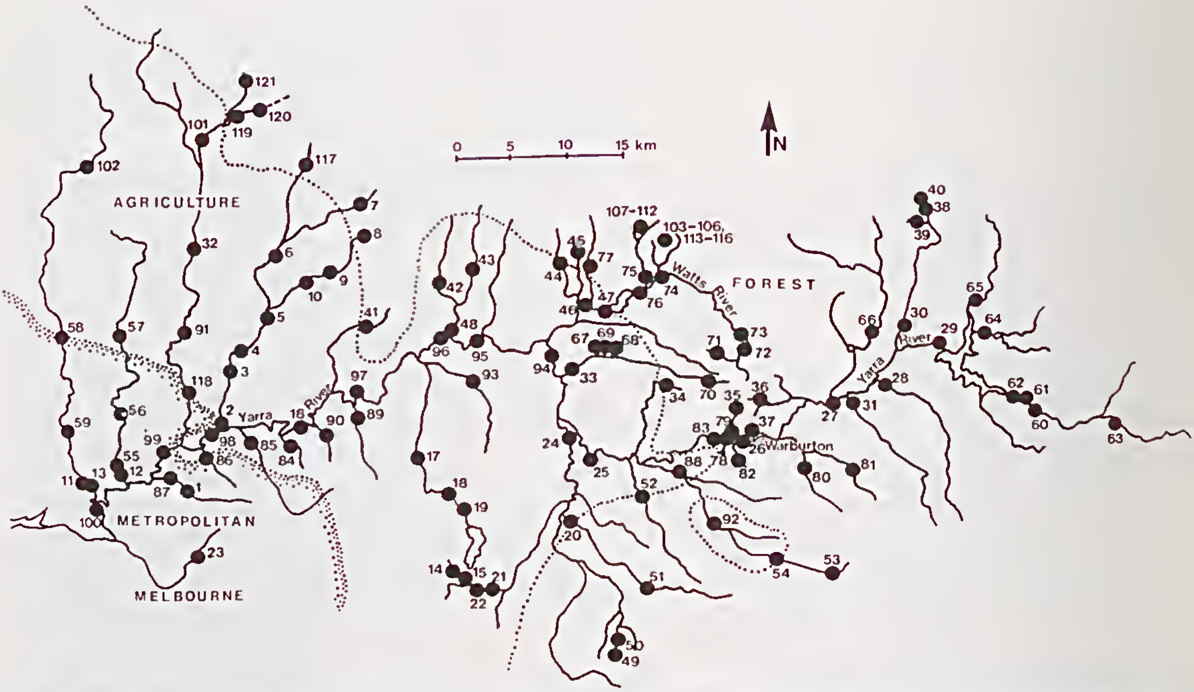


Fig. 1. Yarra River basin showing the sites studied (see Table 1 for details). The approximate limits of urban (stippled line) and agricultural (dotted line) influences are indicated.

Table 2. Modified Pickett-Heap's Diatom Media (DM).

$Ca(NO_3)_2.4H_20$	0.70 g
$KH_2P0_4.7H_20$	0.06 g
$MgS0_4.7H_20$	0.20 g
Trace Element Mix	5 mL
Vitamin Mix	1 mL
Soil Extract	40 mL
"Micropore" filtered H_20	1000 mL

Variation 1 (to induce sexuality in Zygnemataceae):
1. Omit $Ca(NO_3)_2.4H_2O$ and Soil Extract
2. Add $CaCl_2$ 0.80 g

Variation 2 (to grow *Cladophora*):
1. Omit 1/2 of Trace Element Mix
2. Add $NaHCO_3$ 0.03 g
3. Increase amount of $MgSO_4.7H_2O$ to 1.40 g
4. Adjust pH to about 8

Variation 3 (for species from sites with low conductivity):
1. Dilute media by ½–$^1/_{10}$

The main nutrients were added from stock solutions, and with Trace Element Mix and Soil Extract were steamed for 3 hours at 100°C. pH was adjusted to 6–7 with NaOH or HCl. Vitamins were added before use.

Trace Element Mix (1000 mL): $Na_2B_4O_7.10H_2O$ 0.048 g, $CuSO_4.5H_2O$ 0.025 g, $CoCl_2.6H_2O$ 0.024 g, $MnCl_2.4H_2O$ 0.015 g, $ZnSO_4.7H_2O$ 0.029 g, $(NH_4)Mo_7O_{24}.9H_2O$ 0.018 g, $FeSO_4.7H_2O$ 0.028 g, $N(CH_2COOH)_3$ 0.191 g, NTA 20 mL. Made up according to guidelines in Stearn (1973: 36).

Vitamin Mix (500 mL): Cyanocobalamin 2.5 mg, Biotin 2.5 mg, Thiamine.HCl 500 mg.

blue (with 4% molar HCl), and mounted in "Karo" and glycerol respectively.

A portion of most collections was air-dried on cellophane bags (pressed algal filaments on standard herbarium sheets can be difficult to separate from the paper fibers) and filed in folded paper in an index card file. All voucher specimens and slides are deposited in the Melbourne University Herbarium. The suffix p.p. (*pro parte*) is added to the herbarium number where more than one macroalgal taxon is part of the same specimen. Herbarium abbreviations follow Holmgren et al. (1981).

Most plants were photographed from fresh field or culture material. "Nomarski" differential interference contrast was found to be useful for improving the definition of wall and chloroplast shapes.

Analyses

The results (see Appendix) have been analyzed in two fundamental ways: as a function of individual sites, and combined into "strata" for comparison with the EPA water quality data on the Yarra River (Victoria, EPA 1983). It was difficult to reconcile the records of genera and vegetative groups with those of "real" species so, in most analyses, vegetative groups and genera were used when not all records of that group or genus could be identified to species level. This technique also allows the classification system to be field-based for ease of later studies. The TAXON package of programs (on CSIRONET) was used to analyze the data (Table 3).

The NIASM program (Numerical Information Analysis, Single Multistate) was used successfully by Barson (1984) to analyze wetland data, as it is both agglomerative and polythetic. In this respect, it is similar to MACINF (Matrix Generating, Agglomerative, Clustering Information Analysis), also used for vegetation analysis (e.g. O'Brien 1981, Williams & Ashton 1987). NIASM, however, is asymmetric and does not use matching "zeros" to calculate dissimilarity. Both methods were used on the binary data (treating the binary data as a numeric for the NIASM analysis) to compare results. A two-way table was produced by using the distance measures MSED (Standard (squared) Euclidean Distance) on species and MJAC (Jaccard Coefficient) on sites, both clustered with SAHN (Lance/Williams Sequential Agglomerative Hierarchical Non-overlapping Clustering).

The results were further studied using the programs GCOM (Group Comparisons), CRAMER (-Value), PCOA (Principal Co-Ordinates Analysis), and BACRIV (Back Correlation of Individuals on Vectors)(Ross 1986). These techniques helped to identify important distinguishing taxa and chemical or physical parameters, and to clarify relationships between groups. The classification results were assessed visually using DENDRO (dendrograms) and TPLOT (plots).

The EPA data were analysed with MCAN (Matrix using Canberra Metric) and SAHN. These programs used together permit manipulation of data of varying ranges, being sensitive to proportional rather than absolute differences

No.	Individuals	Attributes	Values	Masked[1]	Analysis
1	sites	species	0/1	—	MACINF
2	sites	species	0/1	—	MJAC/SAHN
3	sites	species	0/1	various[2]	NIASM
4	sites	species	0–3	physical data[3]	NIASM
5	strata	species	0–100[4]	EPA data	NIASM
6	strata	EPA data	var.[5]	species data	MCAN/SAHN
7	species	sites	0/1	—	MSED/SAHN

[1] Some attributes can be masked and therefore would not be considered in the analysis (but certain additional programs show how they correlate with the groupings).
[2] Culture species (i.e. identifications to species level based on characters observed in culture) of *Stigeoclonium*, *Oedogonium* and *Spirogyra* (since most populations were sterile); *Vaucheria* sp. (since most species became fertile in culture); and *Schizothrix friesii* (which may include a number of ecophenes).
[3] Include temperature maximum and minimum, urban/agricultural/forest at site and upstream, approximate altitude, stream order).
[4] The frequency of occurrence of each species in a stratum was calculated from the presence/absence data and equals the number of sites present divided by the total number of sites in a stratum, times 100.
[5] Variable depending on the parameter measured (see Victoria, EPA 1982).

Table 3. Programs in the TAXON package used to analyse the data.

between attributes (Clifford & Stephenson 1975). Although the EPA chemical data used for this comparison were measured 5 years before the macroalgal survey took place, the EPA's extensive monitoring could not be replicated within the constraints of this study (instantaneous measurements at the site of collection have only limited value in determining the limits of distribution). The EPA survey used groupings of sites called "strata" which included apparently similar parts of the catchment. The macroalgal data were grouped into these strata (Table 1) and analysed concurrently with the 10 and 90 percentiles and median values for selected EPA data (pH, Conductivity at 25°C, Hardness, Toxicity Mixture, Temperature, DO, Turbidity, Total Nitrogen, Total Phosphorus, Non-Filterable Residues and *E. coli*).

DESCRIPTIONS OF TAXA

All taxonomic ranks used (division, family, genus and species) are listed alphabetically within the next highest rank. The distribution of each taxon has been mapped in Figs 12–16. No information is given about the type elements or type locality of the species since no types were examined; these data can be gleaned from the protologue or other publications cited. The prefix MELU has been omitted from all specimens housed in the University of Melbourne Herbarium.

Unless otherwise indicated, the distributional data for each species has been taken from the publications cited under the species name or from the general texts mentioned below. Family descriptions are given only when the family includes more than one genus found in the Yarra River basin. Illustrations of taxa are provided when new observations or taxonomic changes have been made, or when the taxa previously have been poorly illustrated. Illustrations adequate for the identification of most freshwater algal genera can be found in Bellinger (1980), Bold & Wynne (1985), Bourrelly (1966, 1968, 1985), Prescott (1954) and Smith (1950).

Some desmids (Desmidiaceae) and diatoms (Bacillariophyceae) may be filamentous or colonial, many disintegrating into smaller chains of cells when removed from their habitat. In most cases they occur with other filamentous algae which are more firmly attached to the substrate (e.g. *Cladophora* and *Klebsormidium*). The two most commonly found genera in the Yarra River basin were *Hyalotheca* (Desmidiaceae; e.g. specimens TJE812, TJE813, TJE809) and *Melosira* (Bacillariophyceae; e.g. TJE810, TJE814, TJE873, TJE934, TJE948), both usually in eutrophic streams. A colonial *Cosmarium* (Desmidiaceae) was found on a North Maroondah weir (TJE1373). Many other taxa were present as single-celled or short filamentous epiphytes. No desmids or diatoms are described here, but they should be included in any account of the microalgae of the Yarra River basin.

A list of Australian literature and ex-MELU herbarium records for all the taxa described in this paper has been prepared and can be obtained from the author.

Key to families of macroalgae in Yarra River basin

(based on vegetative structures)

The family provides a convenient and generally easily recognizable taxonomic group for the freshwater macroalgae. The key provided here applies only to those genera of the family found in the Yarra River basin, and not to each family as a whole. The keys to genera and species are nested within the text.

1. Photosynthetic material not in chloroplasts; cytoplasm of even or granular texture 2
— Chloroplast(s) discrete, compartmented from rest of cytoplasm 4
2. Cell L/D mostly > 3, trichomes tapering . . . . Loefgreniaceae (Cyanophyta)
— Cell L/D < 3, trichomes not tapering throughout 3
3. Heterocysts present or absent; trichomes either deeply constricted at crosswalls (*Anabaena*) or arranged in erect, tufty, branched aggregates (*Scytonema*) . . . . Nostocaceae (Cyanophyta)
— Heterocysts absent; trichomes not or little constricted at cross walls, arranged irregularly in prostrate mucilaginous mat . . . . Oscillatoriaceae (Cyanophyta)

4. Thallus either membranous, tubular, or colonial 5

— Plants filamentous or siphonous 7

5. Thallus parenchymatous, tubular or membranous .... Ulvaceae (Chlorophyta)

— Thallus colonial, saccate or ribbon-like 6

6. Plants brown or yellow; cells in outer layer of rubbery sac .... Chrysocapsaceae (Chrysophyta)

— Plants bright green; cells throughout mucilaginous colony .... Tetrasporaceae (Chlorophyta)

7. Branched siphons .... Vaucheriaceae (Chrysophyta)

— Branched or unbranched filaments (with crosswalls) 8

8. Cells with single stellate chloroplast; cells in irregular uniseriate row, with thick mucilage .... Porphyridiaceae (Rhodophyta)

— Cells never with one stellate chloroplast (may have two); cells in regular, usually uniseriate rows, never embedded in thick mucilage 9

9. Filaments unbranched; unstressed vegetative cells with walls less than 2µm thick 10

— Filaments branched or (in *Rhizoclonium*) unbranched; if unbranched, all vegetative cells with stratified walls more than 2µm thick 13

10. Ends of at least some cells encircled by scars ("rings") from successive ruptures of cell wall during vegetative growth; chloroplast reticulate .... Oedogoniaceae (Chlorophyta)

— Cells without encircling scars; chloroplast(s) entire, variously shaped 11

11. Chloroplast(s) either axial, or parietal and ribbon-like; with prominent pyrenoids .... Zygnemataceae (Chlorophyta)

— Chloroplast(s) parietal but never ribbon-like; with or without pyrenoid(s) 12

12. Chloroplasts one or many per cell, yellow-green; H-shaped wall pieces present (sometimes obscure); cell L/D usually > 2 .... Tribonemataceae (Chrysophyta)

— Chloroplasts one per cell, green; H-shaped wall pieces present or absent; cell L/D usually < 2 .... Ulotrichaceae (Chlorophyta)

13. Plants with fascicles of determinate laterals arranged around a main axis 14

— Plants without fascicles of determinate laterals 15

14. Plants green, disintegrating readily; fascicles irregularly arranged, not in whorls .... Chaetophoraceae (Chlorophtya)

— Plants green, red, purple or brown; not readily disintegrating; fascicles arranged regularly in whorls at each node of axial cells .... Batrachospermaceae (Rhodophyta)

15. Plants with single pseudoparenchymatous cortical layer enclosing large axial cells .... Compsopogonaceae (Rhodophyta)

— Plants not corticate, uniseriate throughout 16

16. Cells with pit-connections; plants usually red, brown, violet or olive-green .... Rhodochortaceae (Rhodophyta)

— Cells without pit-connections; plants green 17

17. Ends of branches or filaments rounded; chloroplasts many, discoid, arranged in a reticulum .... Cladophoraceae (Chlorophyta)

— Ends of branches acutely pointed, often extending into hairlike cells; chloroplasts laminate and parietal, one per cell .... Chaetophoraceae (Chlorophyta)

Chlorophyta

Chaetophoraceae Greville 1824: xix, 321.

Plants consisting of branched filaments; terminal ends generally acutely pointed, often with hairlike apical cells. Reproduction by zoospores and fusion of isogametes.

Chaetophora Schrank 1783: 125. Hazen 1902: 209. Fritsch 1935: 254. Smith 1950: 155. Bourrelly 1966: 276.

Filaments forming gelatinous globose colonies; no abrupt change in cell diameter throughout plant; outer cells with a single chloroplast covering entire periphery of cell; inner cells with band-like chloroplast.

Chaetophora elegans (Roth) C. Agardh 1812: 42. Hazen 1902: 211, pl. 37.

Distribution. Cosmopolitan; Yarra River basin (Fig. 12A).

Specimens examined. Site 117: TJE1412, TJE1429.

Plants globose to tuberculate, gelatinous, light green; filaments radiating from central region; outer branching monopodial, often secund, with usually one, sometimes two, laterals from each node, usually erect; inner branching apparently dichotomous, more sparse, generally lax and spreading; cells throughout cylindrical to barrel-shaped, 4–30 μm long, 5–13 μm in diameter, L/D 0.5–6; apices of filaments acute, sometimes with long, hairlike cells.

Reproduction (not seen) by biflagellate zoospores and akinetes; germination of zoospores and growth of new plants occasional within gelatinous matrix of mature plant.

Habitat and phenology. Plants were found on rocks in splash zone of weir in spring; water temperature was 10°C. The species was associated with *Batrachospermum atrum* in a part of the catchment with fairly soft water (Ca 8.0 mg/L, Mg 1.2 mg/L).

Blum (1957) found *Chaetophora elegans* and *C. pisiformis* in the unpolluted reaches of the Saline River in the United States, where the water was high in bicarbonates. Johansson (1982) found *C. glomerata* in water with a relatively high pH in Scandinavia. In contrast to these two records, Whitford & Schumacker (1968) described *C. incrassata* and *C. pisiformis* as algae of soft-water acid streams.

Draparnaldia Bory de St-Vincent 1808: 399. Hazen 1902: 217. Collins 1909: 302. Smith 1950: 156. Forest 1956: 1. Bourrelly 1966: 279. Bold & Wynne 1985: 171.

Plants consisting of mucilaginous, usually moniliform, bright green, branched primary axes attached by rhizoids; cells of main axes relatively large, with parietal, equatorial, cylindrical, often fimbriate, chloroplasts; some or all bearing determinate or indeterminate laterals with parietal chloroplasts; gross morphology similar to *Batrachospermum* (Rhodophyta) but plants extremely flaccid and prone to disintegration after collection.

Reproduction mainly by quadriflagellate zoospores, but also by akinetes, aplanospores and conjugation of quadriflagellate isogametes.

Draparnaldia mutabilis (Roth) Bory de St-Vincent 1808: 402, pl. 35, fig. 1a–d.

Draparnaldia glomerata (Vaucher) C. Agardh 1812: 41.

Draparnaldia plumosa (Vaucher) C. Agardh 1812: 42.

Draparnaldia acuta (C. Agardh) Kützing 1845: 230.

Distribution. Cosmopolitan; Yarra River basin (Fig. 12B)

Specimens examined. Site 19: TJE1131; site 21: TJE833; site 26: TJE1024, TJE1058, TJE1280, TJE1351 p.p., TJE1419; site 27: TJE859, TJE1055, TJE1332; site 28: TJE865, TJE1349, TJE1415; site 30: TJE868; site 62: TJE949, TJE1198; site 78: TJE985; site 79: TJE1001.

Thallus up to 100 mm long, 450–800 μm in diameter at maturity. Main axis cylindrical to moniliform; cells 25–90 μm in length, 20–58 μm

Key to genera of Chaetophoraceae

1.	Plants with distinct main axis of stout cells bearing whorls of determinate laterals	*Draparnaldia*
—	Plants not differentiated into main axis and determinate laterals ...	2
2.	Plants colonial, globular; filaments embedded in gelatinous matrix	*Chaetophora*
—	Plants not colonial or globular; filaments forming mucilaginous tufts	*Stigeoclonium*

in diameter, L/D 0.8–2.0(–2.5); chloroplast parietal, equatorial, cylindrical and fimbriate, with numerous pyrenoids; fascicles bi- and tri-furcate, arising apically from some axial cells; axes of fascicles either prominent, almost indeterminate (usually in juvenile plants), or indistinct and clearly determinate throughout; proximal cells cylindrical to doliform, 10–30 µm long, 5–15 µm in diameter, L/D 1.0–4.0; distal cells obconical or truncate obconical, 10–20 µm long, 3–5 µm maximum diameter, L/D 3.5–6.0, usually terminated by uni- or multi-cellular hair, up to 350 µm long; chloroplasts parietal, usually with one or two pyrenoids.

Zoosporangia formed in fascicle cells; zoospores germinating directly into branched, often curved filament; cells of germling similar to those of mature fascicle.

Habitat and phenology. Plants were common in spring and summer but rare or absent in winter; water temperatures were 7–19°C. *D. mutabilis* grows in the upper Yarra and Watts River basins where there is some opening of the canopy. It can occur as isolated plants, as in the Yarra River near Warburton, or in dense blooms, as in the Yarra River below the O'Shannassy River inlet. *D. mutabilis* (as *D. glomerata*) was found by Fjerdingstad (1965) to be mostly an alga of non-polluted areas in Scandinavia, although capable of growing successfully in polluted streams. Van Beem & Simons (1988) found *D. mutabilis* in both eutrophic, hard water, and in mesotrophic, soft water but growths were more extensive in the latter environment.

Three of the species of *Draparnaldia* recorded from Victoria by Watts (1865), *D. elongata*, *D. tenuis* and *D. nana*, are referrable to *Stigeoclonium* (Islam 1963). The other two species, *D. plumosa* and *D. glomerata*, are here considered to be synonyms of *D. mutabilis*. Prior to 1865, *D. mutabilis* occurred as far downstream in the Yarra River as Heidelberg; today, its lowest apparent occurrence is some 80 km farther upstream at Warburton. This is paralleled by Watts' collection at Heidelberg of the red alga *Nothocladus nodosus* Skuja, which is now also only known from the Upper Yarra region (Entwisle & Kraft 1984).

Taxonomic remarks. Variations in fascicle shape with age of plant and habitat have been reported for several *Draparnaldia* species by a number of authors (Bory de St-Vincent 1808, Uspenskaja 1930, Suomalainen 1933, Forest 1956, van Beem & Simons 1988), and only one discrete entity could be delimited in the Yarra River flora. This taxon includes plants similar to those described by Bory de St-Vincent (1808) as *Draparnaldia mutabilis* (non *D. mutabilis* (Roth) Cedergren 1920). The list of synonyms given above is taken from Forest (1956) and Bory de St-Vincent (1808), and is consistent with an examination of the relevant protologues.

No other alga in the Yarra River system besides *Draparnaldia* and the Batrachospermaceae has a thallus differentiated into a main axis and fascicles of determinate laterals. *Draparnaldia mutabilis* differs from genera in the Batrachospermaceae (Rhodophyta) in not having regular whorls of fascicles, and in having axial cells that are short and cylindrical to doliform rather than long and cylindrical. In addition, cells of *D. mutabilis* lack the pit connections of red algae, reproduction is very different, and plants of *Draparnaldia* disintegrate more easily when collected.

Stigeoclonium Kützing 1843: 253 (as *Stygeoclonium*); corr. 1849: 352 (nom. cons.). Smith 1950: 153. Islam 1963: 49. Printz 1964: 126.

Myxonema E.M. Fries 1825: 343. Hazen 1902: 193.

Distribution in Yarra River basin. See Fig. 12C.

Plants bright green; axes branched, mostly uniseriate (although oblique cell divisions occasionally create limited zones of multiseriate tissue), without abrupt changes in cell size; distal cells somewhat attenuated, sometimes bearing long, multicellular hair; chloroplasts in larger cells parietal cylindrical, sometimes fimbriate, with several pyrenoids; in smaller cells parietal with 1–3 pyrenoids; erect system attached by discoid cell, rhizoids, or irregularly branched to pseudoparenchymatous prostrate system.

Reproduction usually by quadriflagellate ovoid zoospores, formed inside intercalary or terminal cells; sexual reproduction seldom reported, apparently taking place by conjugation of bi- or quadri-flagellate isogametes; thick walled cells produced under some conditions; zoospores germinating to form prostrate or erect (not seen) primary filament.

Remarks. To identify species of *Stigeoclonium* it is necessary to examine the prostrate thallus, either in culture or on artificial substrata in the field. In their comprehensive study of species concepts in the genus, Cox & Bold (1966: 7) stated that they were "well aware that increased emphasis on the culture method, and on morphological attributes which are not immediately visible in collected materials, will not please those who seek to simplify the identification of *Stigeoclonium* in the field. However, if it were now possible to identify species of *Stigeoclonium* easily and reliably in the field, this investigation would not have been necessary".

More recent studies (e.g. Francke 1982; Francke & Simons 1984; Simons et al. 1986) have supported the main findings of Cox & Bold (1966), and species delineation in *Stigeoclonium* is now based on characteristics of the prostrate system and germination pattern, features usually only observable in plants grown from zoospores on a surface which can be examined microscopically (e.g. glass slides). The more "convenient" characters displayed by the erect system, used by Islam (1963) and Printz (1964), apparently do not reflect the full range of "normal phenotypic expressions of the organism" (Cox & Bold 1966: 22).

Simons et al. (1986) recognised three species of *Stigeoclonium*, two of which occur in the Yarra River catchment. Although some populations from the upper parts of the catchment resemble the third species, *S. helveticum*, in protrate thallus morphology, it was not possible to delimit these populations clearly from *S. tenue* on the basis of the material observed.

Habitat and phenology. Both species were more common in the cooler months but grew to some extent throughout the year. Water temperatures ranged from 8–25°C. *Stigeoclonium tenue* and *S. farctum* can tolerate an extremely wide range of eutrophication. They occur throughout the basin, from the most polluted urban streams to mountain weirs. There is always some physical disturbance at the site, but the nutritional demands of *Stigeoclonium* are unknown. Plants can tolerate relatively high levels of many metals (McLean 1974) and often grow on submerged iron if present. It is probable that *S. tenue*, the most widespread species, will spread throughout the catchment as filaments are dispersed through human activity. Although Fjerdingstad (1965) characterised *S. tenue* as a common species tolerant of mildly polluted waters, Biggs & Price (1987) found *Stigeoclonium* more commonly in streams with few electrolytes. McLean & Benson-Evans (1974) and Fjerdingstad (1965) have aptly described *S. tenue* as an organism which, although common in organically polluted streams, is not restricted to this environment.

There seems to be no habitat distinction between *S. tenue* and *S. farctum*, and detailed studies of microhabitat are needed. In some sites (e.g. site 13) both species were present.

Stigeoclonium farctum Berthold 1878: 193, pl. 15, fig. 15, pl. 16, figs 1–5. Simons et al. 1986: 216, figs 27–36.

Distribution. Cosmopolitan; Yarra River basin (Fig. 12D).

Specimens examined. Site 12: TJE925, TJE926, TJE1433; site 13: TJE828, TJE938; site 23: TJE843; site 32: TJE876; site 57: TJE932; site 59: TJE935; site 84: TJE1013; site 86: TJE1017.

Germination of zoospores prostrate, producing flat thallus, usually pinnately branched; prostrate thallus becoming pseudoparenchymatous due to density of much branched filaments, at least in centre; intercalary cells cylindrical to ellipsoid, 7–23 µm long, 5–6 µm in diameter, L/D 1.0–5.0; peripheral cells obconical to elongate dome-shaped, 8–17 µm long, 3–5 µm in diameter, L/D 1.5–7.0; erect system often poorly developed, up to 10 mm long, with little differentiation of main axis; intercalary cells cylindrical, 9–35 µm long, 5–13 µm in diameter, L/D 1.5-5.0; apical cells obconical 8-17 µm long, 3–5 µm in diameter, L/D 2.5–6.0, or terminated by multicellular hair to 85 µm long.

Stigeoclonium tenue (C. Agardh) Kützing 1843: 253. Simons et al. 1986: 216, figs 13–26.

Key to species of *Stigeoclonium*

(based on results of Simons et al. 1986)

1. Germination of zoospore erect; prostrate system a single holdfast cell, sometimes with short rhizoids, or rarely a branched, few-celled filament terminated by rhizoids .... *S. helveticum* (not found)
— Germination of zoospore prostrate; prostrate system extensive and conspicuous 2
2. Prostrate system open, irregularly branched .... *S. tenue*
— Prostrate system pseudoparenchymatous, at least centrally, and almost pinnately branched .... *S. farctum*

Distribution. Cosmopolitan; Yarra River basin (Fig. 12E).

Specimens examined. Site 11: TJE1082; site 13: TJE1451; site 16: TJE841, TJE1121; site 21: TJE833; site 22: TJE1140; site 24: TJE848; site 26: TJE855; site 29: TJE1234; site 55: TJE928; site 56: TJE930, TJE1077; site 61: TJE948; site 78: TJE1029; site 80: TJE1236; site 83: TJE1290, TJE1341; site 87: TJE1019, TJE1264; site 91: TJE1363.

Germination of zoospores generally prostrate, producing non-compact, irregularly branched prostrate thallus; intercalary cells cylindrical to doliform, 8–19 µm long, 3–8 µm in diameter, L/D 1–6.5; distal cells conical or elongate dome-shaped to subglobose, 5–20 µm long, 2–5 µm in diameter, L/D 1.5–7.0; erect system up to 20 mm long, with little differentiation of main axis; intercalary cells cylindrical, 5–33 µm long, 3–8 µm in diameter, L/D 1.5–11; apical cells conical, 12–23 µm long, 2–3 µm in diameter, L/D 4–8, or terminated by multicellular hair up to 100 µm long.

Stigeoclonium sp.

Specimens examined. (Excluding any from sites where at least one species determination has been possible). Site 1: TJE820, TJE824; site 2: TJE1084; site 3: TJE1086; site 25: TJE850, TJE851; site 45: TJE1369; site 58: TJE1073; site 100: TJE1274; site 104: TJE1397; site 107: TJE1374, TJE1375; site 108: TJE1377; site 109: TJE1378; site 111: TJE1383; site 112: TJE1381; site 114: TJE1385.

Remarks. These collections include only those where no prostrate system was available for examination.

Cladophoraceae Wille 1884: 30. Womersley 1984: 166.

Plants of branched or unbranched uniseriate filaments with parietal reticulum of numerous discoid chloroplasts; some chloroplasts with pyrenoids. Asexual reproduction by bi- and quadri-flagellate zoospores; sexual reproduction (where present) by fusion of biflagellate gametes.

Cladophora Kützing 1843: 262 (nom. cons.). Smith 1950: 213. van den Hoek 1963: 5; 1982: 30. Womersley 1984: 185.

Plants consisting of branched erect filaments attached by single holdfast cell or by rhizoids; cells with numerous angular to discoid chloroplasts forming reticulum or continuous parietal layer, pyrenoids present in most chloroplasts. Reproduction by bi- or quadri-flagellate zoospores and, in some species, conjugation of biflagellate isogametes.

Taxonomic remarks. Although *Cladophora* has been called one of the largest genera of algae (Smith 1950: 215), recent taxonomic studies by van den Hoek (1963, 1982) have greatly reduced the number of accepted species in both marine and freshwater habitats. Van den Hoek (1963) recognised nine species and four varieties of *Cladophora* from fresh waters in Europe and considered most of them to be cosmopolitan.

The key taxonomic characters for species determinations can usually be observed in field material but culturing can help to clarify aspects of holdfast shape and reproductive morphology. Culture studies were used here to confirm the species identification but should not be necessary for subsequent collections from the Yarra River catchment.

Cladophora glomerata (Linnaeus) Kützing 1843: 266. Fritsch 1935: figs 68A, C, 69C, F. van den Hoek 1963: 162, figs 515–519, 522–575. Bourrelly 1966: pl. 75, fig. 7, pl. 76, figs 1–3.

Distribution. Cosmopolitan; Yarra River catchment (Fig. 12F).

Specimens examined. Site 1: TJE801, TJE802, TJE820, TJE1012; site 2: TJE1083; site 11: TJE1081; site 12: TJE827, TJE924; site 13: TJE939; site 17: TJE1372; site 23: TJE838, TJE1096, TJE1192; site 55: TJE927, TJE960, TJE1435; site 56: TJE929; site 57: TJE931, TJE1080; site 58: TJE1072; site 59: TJE1079; site 84: TJE995, TJE1258; site 85: TJE1014, TJE1259; site 86: TJE1016, TJE1260, TJE1261; site 87: TJE1020, TJE1263; site 89: TJE1038, TJE1039, TJE1173; site 90: TJE1041, TJE1069; site 91: TJE1075; site 98: TJE1273; site 100: TJE1274; site 118: TJE1414.

Plants to 1 m long, growth apical and intercalary; branches inserted laterally, obliquely or horizontally, but always from apical portion of cell; pseudodichotomous, alternate, or secund; profuse or sparse; intercalary cells cylindrical to

Key to genera of Cladophoraceae

1. Filaments branched .... *Cladophora*
— Filaments unbranched except for occasional rhizoids .. *Rhizoclonium*

somewhat swollen at ends (particularly in culture), 84–480(–850) µm long, 24–80 µm in diameter, L/D 2.5–12.5(–40), with walls usually 2–5 µm thick but up to 20 µm thick in old cells; in older plants, proximal cells of axis elongate substantially; apical cells dome-shaped, sometimes slightly constricted in middle or at apical end, 84–360(–560) µm long, 16–48(–68) µm in diameter, L/D 3–7.5; basal system of short rhizoids, some terminated by digitate holdfast.

Reproduction by biflagellate zoospores from clavate to hemispherical zoosporangia, 76–144 µm long, 36–88 µm in diameter, L/D 0.7–3; zoosporangia dehiscing through lateral pore near one end of cell.

Habitat and phenology. Plants were common in summer but may persist in slow-flowing water through winter; water temperatures were 8–25°C. *Cladophora glomerata* was common in urban creeks where conductivity (140–2550 µmS/cm), hardness (30–540 mg/L) and pH (usually 6.0–7.8) were always high. Nitrogen and phosphorus were also high but variable in concentration. There does not seem to be any chemical barrier to the growth of this species in many non-urban but eutrophic alkaline creeks, such as Olinda Creek (site 17) where it was present in small amounts. Fjerdingstad (1965) characterised *Cladophora* species as being capable of thriving in both polluted and unpolluted waters. *C. glomerata* seems to be limited to "hard" water, however, and would not grow naturally in the acidic creeks of the upper Yarra catchment. Marker & Close (1982) found *Cladophora* growing in an alkaline but nutrient poor stream. Johansson (1982) listed *C. glomerata* as an indicator species of low altitude streams (less than 400 m above sea level) in Sweden, where most streams are "hard". It also occurs worldwide as a littoral species in lakes and reservoirs.

Cladophora glomerata seems to have prospered in the polluted creeks of Melbourne since European settlement. Ferdinand Mueller, for example, collected *C. glomerata* (as *C. callicoma* and *C. crispata*) from Darebin Creek in 1853. Since Darebin Creek mostly flows through basalt, the water would always have been "harder" than the bulk of the Yarra River catchment, and *Cladophora* may have been a natural population. In the 1850s, however, agricultural and urban development had already severely degraded water quality (Barrett 1971), and the akinetes or filaments (kept moist) of *C. glomerata* could have been brought from Europe. It is curious, though, that Hardy (letter to Prof. Ewart, 1907) stated that *C. crispata* was not known from the Darebin Creek at that time, but it was to be found in the "backwaters" of the Yarra River (Hardy 1906: 35 recorded *C. glomerata* and *C. fracta* from the backwaters of the Yarra River). The absence of the species in Darebin Creek may have been due to the seasonality of *Cladophora* or to a degradation or improvement of water quality at the time.

Filaments of *C. glomerata* in CM media can remain viable for over 6 months in total darkness at 16°C (Entwisle, 1989a). This capacity to withstand long periods without photosynthesis would be important for overwintering and distribution of plants.

Taxonomic remarks. In one collection (TJE1016) the apical cells are particularly long (up to 560 µm) but no populations are morphologically distinct enough to be considered as separate species. A number of distinct genotypes may exist but these cannot be distinguished as taxa in any practical sense. For this reason, *C. fracta* and the varieties of *C. glomerata* described by van den Hoek (1963) are not considered to be useful subdivisions in the Yarra River catchment flora.

Rhizoclonium Kützing 1843: 261. Fritsch 1935: 231. Womersley 1984: 167. Bold & Wynne 1985: 205.

Plants consisting of unbranched filaments, in entangled masses, or attached by short lateral rhizoids (not seen). Asexual reproduction by biflagellate zoospores is uncommon and has not been seen in this study.

Rhizoclonium hieroglyphicum (C. Agardh) Kützing 1845: 206. Collins 1909: 329, pl. 12, fig. 119. Fritsch 1935: figs 69B, G, H, J. Smith 1950: fig. 133. Bourrelly 1966: pl. 73, figs 6, 7.

Distribution. Cosmopolitan; Yarra River basin (Fig. 12G).

Specimens examined. Site 2: TJE1083; site 16: TJE1092.

Cells cylindrical, 27–33 µm in diameter, 35–85 µm long, L/D 1.5–3.0; cell wall stratified, 5–8 µm thick; no rhizoidal or unicellular proliferations seen.

Habitat and phenology. Plants were found in early autumn; water temperature was 12–17°C. Both sites are in the outer suburbs of Melbourne, in or near the Yarra River.

Taxonomic remarks. West (1927) gave a cell diameter range of 10–37 µm and cell L/D of 2–5 for *R. hieroglyphicum*, and these ranges encompass most of the Yarra River basin material. Koster (1955) reported that probable type material of *R. hieroglyphicum* has filaments 18–30 µm in diameter and cell L/D of 1.5–4. Collins (1909), however, reported cell diameters of 10–25 µm in what is purportedly the type variety, and recognised two varieties with broader filaments and, in one case, thicker walls. The recognition of these varieties does not seem warranted on the basis of available evidence.

Koster (1955) suggested that *R. hieroglyphicum* may be synonymous with *R. riparium* (Roth) Harvey but stressed that experimental studies are needed to confirm this. *R. riparium* has filaments 18–48 µm broad and cell L/D of 1–8.5, and thus includes the size range found in Australian plants. Koster (1955) recognised two varieties of *R. riparium*, var. *valdium* Foslie with cells 30–48 µm broad, and the type variety with cells 18–33 µm broad.

The plants from the Yarra River basin are also similar to *Cladophora rivularis* (Linnaeus) van den Hoek (1963), which may be unbranched. In *C. rivularis*, however, the L/D of vegetative cells tends to be larger (3–10), and multicellular rhizoids and occasional, terminally-inserted branches are commonly present.

The distinction between *Chaetomorpha* and *Rhizoclonium* is problematical. In most cases, unbranched filaments of a coarse texture and over 100 µm broad are referred to *Chaetomorpha*. Such plants (TJE1507) form large, tangled, open mats in Korkuperrimul Creek at Bacchus Marsh, in the Werribee River basin.

Oedogoniaceae Hirn 1900: 71.

Oedogonium Hirn 1900: 72. Tiffany 1930: 53. Smith 1950: 207. Bourrelly 1966: 342. Bold & Wynne 1985: 183.

Plants consisting of unbranched, uniseriate filaments; cells cylindrical to capitellate (i.e. broader at one end), most with distinctive cell division scars ("rings") at one end; chloroplasts reticulate, parietal (but sometimes obscured by discoid starch deposits), with one to many pyrenoids; nucleus usually prominent; filaments attached by a single-celled holdfast.

Sexual reproduction oogamous, with intercalary oogonia and various arrangements of male gametangia; asexual reproduction by zoospores and fragmentation; germlings from zoospores first produce holdfasts, then an erect filament, often with a conical apical cap.

Taxonomic remarks. Valid publication of names in the Oedogoniaceae begins in 1900 with Hirn's monograph (see Greuter et al. 1988). As a result, many nineteenth century records of *Oedogonium* are irreconcilable with current species concepts.

Few nanandrous species (i.e. plants with a separate sperm-producing life-phase) are found in rivers, probably due to the disadvantages of alternate generations in a unilaterally flowing system such as a river (cf. Rhodophyta; Sheath 1984). In fact, few male gametangia of any type were found during this study. Since all field collections were sterile, this may be due to the culture conditions used.

As with the family Zygnemataceae, sterile populations falling into several size groupings

Key to species and vegetative groups of *Oedogonium*

1.	Plants with oogonia	2
—	Plants without oogonia (vegetative only)	5
2.	Oogonia usually twice or more diameter of vegetative filament; filament diameter < 20 µm	3
—	Oogonia only little inflated beyond vegetative filament; filament diameter > 20 µm	4
3.	Vegetative cell L/D < 2; oogonia > 35 µm in diameter	*O.* sp. A
—	Vegetative cell L/D > 2; oogonia < 35 µm in diameter	*O. intermedium*
4.	Oospores filling oogonia; oogonia < 60 µm in diameter	*O.* sp. B
—	Oospores leaving at least ends of oogonia empty; oogonia > 60 µm in diameter	*O. crassum*
5.	Vegetative filaments < 15 µm in diameter	Slender-Filament Group
—	Vegetative filaments > 15 µm in diameter	6
6.	Vegetative filaments < 25 µm in diameter	Medium-Filament Group
—	Vegetative filaments > 25 µm in diameter	Broad-Filament Group

have been delineated to facilitate ecological studies. These groupings have no formal taxonomic status and almost certainly include more than one "species". Some may even include filaments of species whose alternate phase or male/female counterpart has been referred to a different vegetative group. Although Whitton et al. (1979) suggested using a doubling geometric series (2,4,8,. . .) for vegetative diameter categories, the divisions used here are based on size disjunctions actually encountered in the populations examined.

Oedogonium crassum Hirn 1900: 139, pl. 18, figs 99–100, pl. 19, figs 100–101. Tiffany 1930: 88, pl. 23, figs 202–207. Gonzalves 1981: 263, fig. 9.142A–C. Mrozińska 1985: 128, figs 147–151.

Distribution. Europe, North and South America, South Africa; Australia; Yarra River basin (Fig. 12H).

Specimens examined. Site 4: TJE1193; site 17: TJE1022, TJE1049, TJE1448, TJE1449; site 48: TJE907; site 89: TJE1051; site 96: TJE1315 p.p.

Plants dioecious; female filaments 48–72 µm in diameter; cells cylindrical, with many pyrenoids in mature cells, 30–68 µm long, L/D 1–2.5; putatively male filaments rarely seen, (18–)28–40 µm in diameter, cells (10–)24–28 µm long, L/D 0.5–1.2, with 1(–2) pyrenoid(s) per cell; male gametangia not differentiated.

Oogonia single, ovoid, ellipsoid or barrel-shaped, 64–84 µm in diameter, 55–100 µm long, pore superior, circular to mouth-shaped (corisiform); oospores globose, rarely ellipsoid, leaving oogonial cavities at ends of oogonium (usually also peripherally), rusty orange-brown, 52–76 µm in diameter; oospore wall smooth. Zoospores produced in culture.

Habitat and phenology. Plants were found throughout the year; water temperature was 10–15°C. All habitats were in streams subject to agricultural runoff.

Taxonomic remarks. The female filaments in the Yarra River basin are broader than those usually recorded for this species (including varieties) but the globose oospores, superior pore and slightly inflated oogonia are distinctive of *O. crassum* (Hirn 1900, Tiffany 1930). No definitive male gametangia were seen but some smaller, possibly male filaments were numerous in the same collection. The plants are therefore presumed to be dioecious. Hirn (1900) established this species from a collection also lacking male filaments.

Oedogonium intermedium Hirn 1900: 94, pl. 5, figs 31, 32. Tiffany 1930: 72, pl. 14, figs 134, 135. Gonzalves 1981: 168, fig. 9.31A–F. Mrozińska 1985: 80, figs 63–67.

Distribution. Cosmopolitan; Yarra River basin (Fig. 12I).

Specimens examined. Site 46: TJE1052 p.p.; site 82: TJE1124.

Plants apparently monoecious; female filaments 15–18 µm in diameter, 7–32 µm long, L/D 0.5–2.

Oogonia single, separated by one vegetative cell or rarely in contiguous pairs, ovoid to pyriform, 25–35 µm in diameter, (20–)27–42 µm long, pore superior; oospore ovoid, c. 27 µm in diameter, c. 27 µm long, filling oogonium. Probable immature male gametangia 5 µm long.

Habitat and phenology. Plants were found in late spring and summer; water temperature was 10–12°C. Habitats were relatively pristine, with little eutrophication.

Taxonomic remarks. The Yarra River basin plants are similar to *O. intermedium* except that the oogonia may be smaller (to 25 µm in diameter rather than the 31–37 µm usually reported). No mature male gametangia were seen.

Oedogonium sp. A

Distribution in Yarra River basin. Fig. 12J.

Specimen examined. Site 96: TJE1315 p.p.

Plants apparently dioecious; female filaments 12–16 µm in diameter; cells 32–53 µm long, L/D 2–4, usually with one pyrenoid. Oogonia ovoid to pyriform, 1–2 together, 35–42 µm in diameter, 45–55 µm long, pore superior; mature oospores not seen. No male gametangia seen.

Habitat and phenology. Plants were collected in winter; water temperature was 12°C.

Taxonomic remarks. This population is similar in some respects to *O. intermedium* as described above but has smaller oogonia and longer vegetative cells. The differences are not substantial and when more material of TJE1315 p.p. is found the two may be best included in the one taxon. The field material was intermediate between the Slender-Filament and Medium-Filament vegetative groups described below.

Oedogonium sp. B

Distribution in Yarra River basin. Fig. 12J.

Specimen examined. Site 46: TJE1052 p.p.

Plants apparently dioecious; female filaments 28–40 µm in diameter; cells 20–52 µm long, L/D 0.7–2. Oogonia globose to compressed globose, 43–50 µm in diameter, 32–45 µm long, pore superior; oospores filling oogonium. Male gametangia not seen. Zoospores formed in normal vegetative cells in culture.

Habitat and phenology. Plants were found in summer; water temperature was 20°C.

Taxonomic remarks. This population is similar to *O. capilliforme* Hirn (1900: 107, pl. 8, figs 49–54) in cell and oogonium dimensions, and in having smooth-walled oospores and barely tumid oogonia. It differs, however, in having oospores which are globose rather than ellipsoid, and which completely fill the oogonium. *O. oryzae* Hirn (1900: 294, pl. 22, figs 113–114) has similar oospore dimensions as well as oospores which fill the oogonium, but the oogonia and oospores are obovoid to subcylindrical. The taxonomic position of the present population may be clarified when male material is found.

Oedogonium (Slender-Filament Group)

Distribution in Yarra River basin. Fig. 13A.

Specimens examined. Site 26: TJE1298, TJE1442 p.p.; site 78: TJE1107.

Cells 11–14 µm in diameter, 22–33 µm long, L/D 2–3.

Habitat and phenology. Plants were found in autumn, winter and spring; water temperature was 10–16°C. All habitats are near Warburton.

Taxonomic remarks. This group is similar to that referred to by Johansson (1982: 19) as *Oedogonium* sp. 1.

Oedogonium (Medium-Filament Group)

Distribution in Yarra River basin. Fig. 13B.

Specimens examined. Site 26: TJE1214, TJE1217, TJE1441; site 28: TJE1323; site 30: TJE1233; site 46: TJE904; site 52: TJE1164; site 61: TJE948; site 67: TJE1180; site 75: TJE977; site 79: TJE1218; site 81: TJE1007, TJE1238; site 82: TJE1010; site 106: TJE1403; site 113: TJE1379; site 116: TJE1393.

Cells 15–25 µm in diameter, (7–)20–35(–90) µm long, L/D (0.5–)1.3–2.3(–5); pyrenoid usually one per cell; filament usually not linear, the cells being slightly disjointed. Zoospores formed in normal vegetative cells and germinating freely in culture.

Habitat and phenology. Plants were found in autumn, winter and spring; water temperature was 7–14°C. This group usually grows with Batrachospermaceae in the upper parts of the catchment, at sites where there has commonly been some disturbance. It was not found in summer, possibly being restricted by temperature.

Taxonomic remarks. TJE948 includes filaments with longer cells (to 90 µm long, L/D to 5) than in other specimens. This group is similar to that referred to by Johansson (1982: 19) as *Oedogonium* sp. 2.

Oedogonium (Broad-Filament Group)

Distribution in Yarra River basin. Fig. 13C.

Specimens examined. Site 2: TJE1083; site 4: TJE1087; site 16: TJE840; site 17: TJE835, TJE836, TJE846; site 25: TJE1152; site 26: TJE1299, TJE1442 p.p.; site 27: TJE860, TJE861; site 28: TJE1416; site 32: TJE874; site 46: TJE904, TJE1247; site 48: TJE907; site 56: TJE1076; site 78: TJE1221, TJE1337; site 83: TJE1309; site 89: TJE1038, TJE1040; site 96: TJE1267, TJE1268; site 100: TJE1275; site 106: TJE1402.

Cells 25–65 µm in diameter, (20–)25–135 µm long, L/D (0.5–)0.9–4.5. Zoospores produced in culture.

Habitat and phenology. Plants were found throughout the year; water temperature was 7–20°C. Most habitats are in the upper Yarra River or the middle Yarra region including Olinda and Brushy Creeks.

Taxonomic remarks. There is a continuous and overlapping range of size classes within this group and no further subdivision was possible. The group includes plants referable to the size groupings labelled *Oedogonium* sp. 3 and *Oedogonium* sp. 4 by Johansson (1982: 19). Some collections (e.g. TJE1337) included isolated filaments thinner than those of the main *Oedogonium* present, possibly male plants or another species, but these were not recorded as separate taxa unless large quantities were found.

Tetrasporaceae (Nägeli) Wittrock 1872: 28 (nom. cons., see Silva 1980: 40, 101).

Coccoid cells arranged in mucilage, not confluent. Reproduction by zoospores or fusion of isogametes.

Key to genera of Tetrasporaceae

1. Cells irregularly arranged in cumulous colony .... *Palmellopsis*
— Cells in parallel rows in ribbon-like sheets .... *Parallela*

Palmellopsis Korshikov 1953: 75. Bourrelly 1966: 100. Bold & Wynne 1985: 120.

A monotypic genus with irregularly arranged, apparently unwalled cells in homogeneous, cumulous mucilage; cells with cup-shaped chloroplast, one large pyrenoid and two contractile vacuoles; cells without flagella or flagella-like appendages.

Palmellopsis gelatinosa Korshikov 1953: 75, fig. 18. Bourrelly 1966: pl. 16, fig. 7.

Distribution. Ukraine (Korshikov 1953), USA (Bold & Wynne 1985); Yarra River catchment (Fig. 13D).

Specimens examined. Site 21: TJE1142; site 26: TJE854, TJE1421; site 29: TJE1152; site 33: TJE1248; site 49: TJE910; site 83: TJE1035, TJE1068, TJE1425, TJE1447; site 106: TJE1400.

Plants forming irregular clumps to about 100 mm in diameter on rocks; cells subglobose to ellipsoid, 6–11 μm long, 5–10 μm in diameter, L/D 1–1.5, usually arranged irregularly but in pairs or tetrahedrons when dividing; in culture, mucilaginous "halos" clearly distinguishable. Reproduction by flagellate spores not seen.

Habitat and phenology. Plants were found in spring, summer and autumn; water temperature was 9–15°C. *P. gelatinosa* occurs sparsely throughout the upper part of the catchment but in large quantities in Coranderrk Creek, Healesville, and in the Yarra River at Millgrove. The isolated plants found at other sites presumably are capable of dominating a habitat under suitable conditions. The species seems to favour high light levels but cool temperatures, as does the closely related *Tetraspora* in the northern hemisphere. *Tetraspora* is believed, however, to be incapable of thriving in polluted waters (Fjerdingstad 1965), whereas *P. gelatinosa* was originally described from a "puddle with polluted water" (Korshikov 1953; translated 1987: 66).

Taxonomic remarks. There are a number of genera similar to the commonly reported stream alga *Tetraspora* except that they have no pseudoflagella. The plants studied here have cells with no appendages, both in field material and in that grown in culture (DM and 0.1 DM media). All previous collections of "*Tetraspora*-like" algae from Victoria have also shown no inclination to form flagella-like appendages (G.T. Kraft, S.C. Ducker, pers. comms). On this basis, the plants are not referred to *Tetraspora* as that genus is currently conceived (e.g. Bold & Wynne 1985).

Palmella Lyngbye differs from the plants described here in not having contractile vacuoles (Bourrelly 1966). *Tetrasporidium* Möbius does have contractile vacuoles but in gross morphology it has two layers of cells with numerous perforations (i.e. a relatively distinct shape; see Iyengar 1932). The marine genus *Pseudotetraspora* Wille, 1906 also has no contractile vacuoles and the chloroplasts may be stellate.

Placing *Palmellopsis* in the Tetrasporaceae (see Silva 1979) of the Tetrasporales emphasises its ecological and phenetic similarity to *Tetraspora.*

Parallela Flint 1974: 358.

A monotypic genus with thallus much-divided, ribbon-like, mucilaginous, composed of almost parallel rows of commonly paired cells; contractile vacuoles, flagella and pyrenoids absent. Reproduction by zoospores.

Parallela novae-zelandiae Flint 1974: 359. Sarma & Chapman 1975: 298. Taylor 1975: 323. Sant'Anna et al. 1979: 101, figs 1–11. Reinke 1983: 22–23, fig. 1.

Fig. 2

Distribution. New Zealand, Brazil, USA; Yarra River catchment (Fig. 13E).

Specimens examined. Site 18: TJE1128; site 21: TJE832; site 26: TJE852, TJE1422; site 42: TJE1358; site 50: TJE912, TJE914, TJE1158, TJE1160, TJE1161, TJE1407; site 52: TJE919; site 60: TJE941, TJE1199; site 74: TJE1187; site 78: TJE1028; site 81: TJE1008; site 88: TJE1037.

Plants up to 100 mm long, attached to rocks or free-floating; thallus anastomose, with cells arranged loosely in mucilage, usually in pairs and rows (Fig. 2B, C), often dividing longitudinally or laterally; cells ellipsoid (sometimes flattened on one side following mitotic division) to cubical (Fig. 2B), 5–10 μm long, 2–6 μm in diameter, L/D 1–3.5, having a single parietal, cup-shaped chloroplast with no pyrenoid, numerous oscillating granules in cytoplasm.

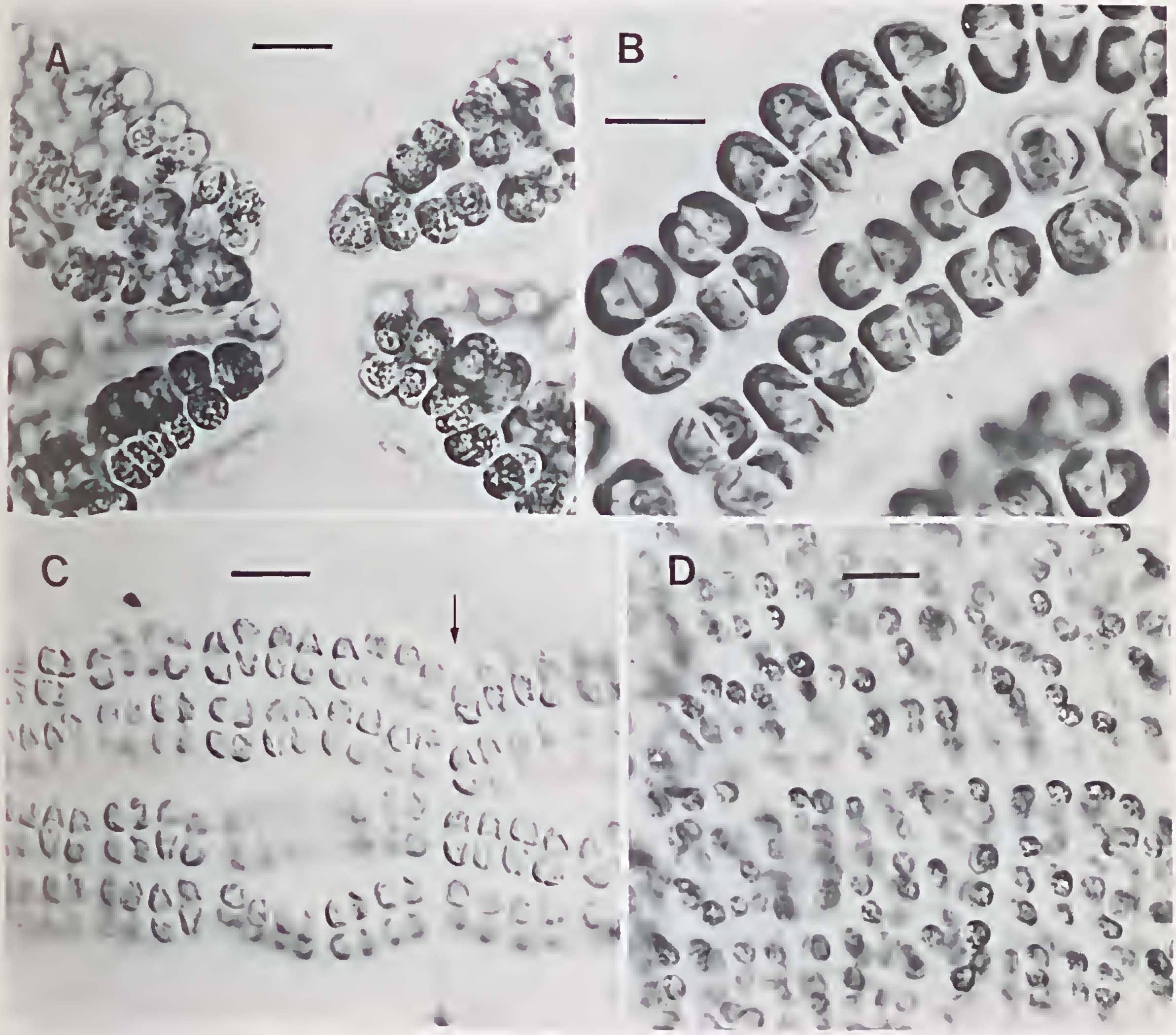


Fig. 2. Parallela novae-zelandiae Flint. A, Anastomosing of biseriate ribbon growth form (TJE1407, scale 20 µm). B, Vegetative plants showing arrangement of paired cells in rows (TJE1358, scale 10 µm). C, Regular anastomosing (arrow) of sheet-like thallus (TJE1128, scale 20 µm). D, Irregular arrangement of cells in aerated culture (TJE1128, scale 20 µm).

Zoospores obovoid, formed in culture from entire vegetative cell after 24 hours continuous darkness.

Habitat and phenology. Parallela novae-zelandiae occurs in the acidic and soft streams of the upper Yarra and Watts River basins in spring, summer and autumn, at water temperatures of 9–16°C. Habitats generally coincide with some opening of the canopy but not with any substantial eutrophication. Flint (1974) reported that all known habitats in the North Island of New Zealand "appear to be relatively rich in nutrients", whereas Taylor (1975) stated that all South Island sites are "probably much poorer in nutrients".

Taxonomic remarks. In static liquid culture media (0.1 DM), the thallus disintegrated and formed zoospores. These zoospores developed into small, irregularly-shaped masses as recorded by Flint (1974) and Sant'Anna et al. (1979). In aerated media (0.1 DM), the normal ribbon-like thallus was maintained but the production of autospores was apparently inhibited. The resulting thallus sometimes appeared more disorganised than in field material (i.e. lacking the regular pattern of paired cells; Fig. 2D). Vegetative cells were mostly 5–8 μm long but in some populations (TJE912, TJE914, TJE1158, TJE1160, TJE1161, TJE1187, TJE1199, TJE1407) larger cells, usually 8–12 μm long, were arranged in pairs of uniseriate or biseriate filaments which joined together regularly rather than in a sheet (Fig. 2A). This morphology is similar to that of the cyanophyte *Heterohormogonium schizodichotomum* J.J. Copeland. The difference in habit amongst populations of *P. novae-zelandiae* may be due to physical factors such as water velocity which may cause splitting of the sheet into narrow units. Reinke (1983) found *P. novae-zelandiae* with cells 8.5–14.0 μm long but with a sheet-like structure similar to that reported in the protologue. Consequently, the two growth forms encountered in the present study are not considered worthy of taxonomic distinction.

Ulotrichaceae Kützing 1843: 179, 251. Womersley 1984: 128.

Plants of unbranched, uniseriate filaments with a single parietal, band-shaped chloroplast. Reproduction by bi- or quadri- flagellate zoospores, fusion of biflagellate gametes, aplanospores or akinetes.

Remarks. Where possible, plants have been referred to three genera, *Klebsormidium, Microspora* and *Ulothrix*. These are distinguished mainly on the basis of chloroplast shape, the presence or absence of pyrenoids, and zoospore morphology. Lokhorst & Vroman (1972: 465) warned that "when only a few filaments [of *Ulothrix*] have been isolated, no conclusions can be drawn regarding the identity of the taxon and certainty may only be obtained by culturing". Since it was not feasible to isolate all ulotrichalean plants in culture, poorly represented taxa are either omitted or included in Ulotrichaceae indet.

A fourth genus, *Cylindrocapsa* Reinsch, has been found in a pool below the Maroondah Dam (TJE168) but as it was not growing in flowing water it is not described here.

Ulotrichaceae indet.

Distribution in Yarra River basin. Fig. 13F.

Specimens examined. Site 9: TJE807; site 27: TJE862 p.p.; site 28: TJE1348, TJE1418; site 34: TJE1409; site 35: TJE882, TJE1250, TJE1251; site 36: TJE885, TJE1253 p.p.; site 45: TJE901, TJE1367; site 47: TJE905; site 59: TJE933; site 69: TJE962; site 70: TJE967; site 108: TJE1376.

Taxonomic remarks. These collections include filaments with a *Klebsormidium/Stichococcus* type chloroplast (unlobed, plate-like, and covering less than half the cell circumference) and no visible pyrenoid. Most of them were not isolated in culture but, of those which were, some dissociated fully and may be referable to *Stichococcus*, possibly to *S. scopulinus* Hazen. The cells are generally less than 8 μm in diameter and have no obvious pyrenoid. A few (e.g. TJE967, TJE905) had a typical *Klebsormidium* habit in the field.

Klebsormidium Silva, Mattox & Blackwell 1972: 643. Bold & Wynne 1985: 159.

Hormidium Kützing 1843: 244. Smith 1950: 146.

Stichococcus auct. non Nägeli. Hazen 1902: 158, pro parte.

Chlorhormidium Fott 1960: 149. Bourrelly 1966: 244.

Plants consisting of unbranched, uniseriate filaments with parietal, entire, usually elongate elliptical chloroplast, with one pyrenoid, and usually encircling less than half cell perimeter. Asexual reproduction by biflagellate, astigmatic zoospores, not producing a holdfast when germinating.

Key to genera of Ulotrichaceae

1. Chloroplast granular, sometimes perforate, without pyrenoid; H-shaped wall structure visible in at least some cells .... *Microspora*
— Chloroplast a continuous sheet, with one or more pyrenoids usually visible; no H-shaped wall structure 2
2. Chloroplast entire, encircling about half cell perimeter or less, usually with one large pyrenoid visible; zoospores astigmatic; filaments > 7 μm in diameter (in Yarra River basin) .... *Klebsormidium*
— Chloroplast lobed longitudinally, encircling more than half cell perimeter, with one or more pyrenoids; zoospores stigmatic; filaments usually < 7 μm in diameter (in Yarra River basin) .... *Ulothrix*

Remarks. Silva et al. (1972) discussed the nomenclature of this genus and their reasons for proposing the name *Klebsormidium* to replace *Hormidium*. Species referable to this genus were included in *Stichococcus* sensu lato by Hazen (1902).

Klebsormidium rivulare (Kützing) Morison & Sheath 1985: 130, figs 4–9, 12–15, 19–22.

Hormidium rivulare Kützing 1845: 192. Ramanathan 1964: 84, pl. 3, fig. D, pl. 22, figs O–R.

Stichococcus rivulare (Kützing) Hazen 1902: 167, pl. 22, figs 10–13.

Distribution. Cosmopolitan; Yarra River basin (Fig. 13G).

Specimens examined. Site 8: TJE806; site 26: TJE1298, TJE1325, TJE1326, TJE1335 p.p., TJE1350; site 27: TJE862 p.p.; site 28: TJE1323, TJE1348 p.p.; site 32: TJE875; site 36: TJE1253 p.p., TJE1408; site 38: TJE887; site 51: TJE917; site 55: TJE1327; site 78: TJE1306, TJE1352, TJE1424; site 83: TJE1322, TJE1354.

Filaments with geniculations ("elbows") and mucilaginous holdfast pads; cells 7–15 µm in diameter, 4–14 µm long, L/D 0.5–2; cell wall 0.5–4 µm thick; cells may contain lipid globules and chloroplast shape may be distorted following stress; chloroplast parietal, plate-like, oval to squarish, usually extending through entire cell longitudinally.

Zoospores astigmatic, rounding up into spheres 4–5 µm in diameter, released from a lateral opening in zoosporangia. Akinete-like cells may be formed by thickening of walls in all vegetative cells.

Habitat and phenology. Plants were found in autumn, winter and spring, at or above water level in rivers; water temperature was 5–15°C. *K. rivulare* tolerates desiccation, often appearing as dull green dried filaments on exposed rocks. It occurs throughout the catchment in the cooler months but in mountainous areas can also grow in the warmer months. It seems to tolerate eutrophication, and also grows in small intermittently-flowing creeks in the hills.

Taxonomic remarks. The plants described are similar to those identified as *K. rivulare* by Morison & Sheath (1985). Although variation in some species of the genus has been studied in culture (Mattox & Bold 1962), the degree of environmental influence on the production of geniculations has not been evaluated (Mattox & Bold did not have any isolates referable to *K. rivulare*). *K. rivulare* differs from the commonly reported species *K. flaccidum* in the production of these geniculations, in its tendency not to fragment, and in its riverine rather than terrestrial habitat (Hazen 1902, Ramanathan 1964). Mattox & Bold (1962) discounted the tendency to fragment as a useful taxonomic character within the Ulotrichales. Since the geniculations and rhizoids seem to be produced in response to contact with the substratum (Hazen 1902), it may be possible for a riverine habitat to induce such structures in *K. flaccidum*- like plants. Ramanathan (1964) noted that *K. rivulare* has constrictions at the septa whereas *K. flaccidum* does not. Hazen (1902) reported these constrictions in both species, but no actively growing filaments collected in the Yarra River basin had any such constrictions (under stress, the thickened walls were constricted at the septa).

Morison & Sheath (1985) did not give cell measurements for *K. rivulare* but the filaments they illustrated range from 7.5–13 µm in diameter. Ramanathan (1964) gave 4–11 µm for the filament diameter of *K. rivulare* and 5–11 µm for *K. flaccidum*, whereas Hazen (1902) gave 8–11 µm and 6–9.5 µm respectively. All plants definitely referable to *Klebsormidium* in the present study have filaments greater than 7 µm in diameter, those plants with the broadest filaments (14-15 µm in diameter) also having the thickest walls (up to 4 µm). Morison & Sheath (1985) have shown the effect of the environment on wall thickness and structure. As no other characters could be found to distinguish taxa, all collections of *Klebsormidium* from the Yarra River basin have been included in *K. rivulare*.

The distinction between *Klebsormidium* and other ulotrichalean algae such as *Stichococcus scopulinus* Hazen, 1902 are not clear. Despite the studies of Mattox & Bold (1962), generic and specific concepts in *Klebsormidium* and *Stichococcus* are still ill-defined. Some of the populations found in the Yarra River basin were difficult to classify due to the deteriorated state of the chloroplast, lack of material to study in culture, or the intermediate and variable nature of key characters. Doubtful identifications have been listed above as Ulotrichaceae indet.

Microspora Thuret 1850: 221. Hazen 1902: 167. Smith 1950: 148. Bourrelly 1966: 252. Bold & Wynne 1985: 162.

Plants consisting of unbranched, usually unattached, uniseriate filaments; cells with parietal, granular chloroplast, which is sometimes perforate; pyrenoid lacking; nucleus lying in bridge of cytoplasm in middle of cell. Asexual reproduction (not seen) by bi- or quadri-flagellate zoospores and by akinetes.

Remarks. Some earlier authors (e.g. Collins 1909) used the name *Conferva* Linnaeus for this genus but Hazen (1902) argued convincingly that this is nomenclaturally incorrect. In any case, *Conferva* is now a *nom. rejic.* (Greuter 1988: 128).

Microspora floccosa (Vaucher) Thuret 1850: 221, pl. 17, figs 4–7. Hazen 1902: 173, pl. 24, figs 1–4.

Distribution. Cosmopolitan; Yarra River basin (Fig. 13H).

Specimens examined. Site 7: TJE1088; site 14: TJE1137; site 26: TJE856; site 40: TJE1231; site 42: TJE894; site 51: TJE1163; site 52: TJE919; site 74: TJE974; site 101: TJE1364, TJE1366; site 115: TJE1389.

Cells 10–18 μm in diameter, 12–100 μm long, L/D 1–5.5; cell walls usually about 1 μm thick but up to 4 μm; H-shaped wall structure usually barely visible in intact filaments.

Habitat and phenology. Plants were usually tangled amongst other filamentous green algae in spring and autumn; water temperature was 7–13°C. Most sites are in little-polluted upper and middle Yarra tributaries.

Taxonomic remarks. As akinetes were not seen, the plants described could be referable to *Microspora willeana* Lagerheim, as described by Hazen (1902). *M. floccosa*, however, is a common species worldwide and the older name of the two (they may be only growth forms of the one taxon). Species distinguished by thicker walls, such as *M. willeana*, must be reconsidered following the finding that stress generally produces thicker cell walls in filamentous green algae (see Morison & Sheath 1985).

Ulothrix Kützing 1833: 517. Hazen 1902: 145. Smith 1950: 142. Mattox & Bold 1962: 19. Bourrelly 1966: 240. Lokhorst & Vroman 1972: 449. Bold & Wynne 1985: 158.

Hormiscia Areschoug 1866: 12.

Uronema Lagerheim 1887: 517.

Plants consisting of unbranched, uniseriate filaments with a parietal chloroplast; chloroplast with lobed or wavy longitudinal edges, often with more than 1 pyrenoid, at least in older cells, encircling more than half the cell perimeter. Asexual reproduction by quadriflagellate, stigmatic zoospores which, in some species, germinate to produce a holdfast.

Remarks. Hazen (1902) and Mattox & Bold (1962) discussed the synonymy of *Ulothrix* with *Hormiscia* and *Uronema* respectively.

Ulothrix subtilis Kützing 1845: 197; emend. 1849: 345. Lokhorst & Vroman 1972: 456, figs 3, 4.

Ulothrix subtilissima Rabenhorst 1863: 263. Ramanathan 1964: 37, pl. 3M.

Distribution. Cosmopolitan; Yarra River basin (Fig. 13I).

Specimens examined. Site 9: TJE813; site 11: TJE825; site 26: TJE1335 p.p.; site 28: TJE1328, TJE1348 p.p.

Cells 3–8 μm in diameter, 3–23 μm long, L/D 0.5–6, terminal cell of young (2–4 celled) filaments acute but becoming rounded with age; chloroplast covering more than half of cell perimeter, sometimes entire perimeter, with 1–4 pyrenoids; attachment to substratum by gelatinous secretion from basal cell; cells may separate following nutrient depletion of media, sometimes fully dissociating; storage products accumulating in older filament, obscuring chloroplast.

Akinetes ellipsoid to spherical, 8–10 μm in diameter, 8–13 μm long, produced singly, or in series. Quadriflagellate zoospores ovoid, 6–8 μm in diameter, 8–14 μm long, with red stigma.

Habitat and phenology. Found in late winter and early spring; water temperature was 8–13°C. The habitats show apparent ecological disparity, ranging from the upper Yarra to the lower reaches of Merri Creek. Although Biggs & Price (1987) found *U. zonata* in New Zealand streams with low conductivity, Fjerdingstad (1964) and Benson-Evans et al. (1975) reported that some populations of *U. zonata* can be pollution tolerant. In Australia, Chessman (1982) found *Ulothrix* sp. in the north-western part of the Latrobe River basin, where water quality was generally high but some sites had elevated nitrate levels.

Taxonomic remarks. The plants were identified to species by using the criteria of Lokhorst & Vroman (1972, 1974a, 1974b), who defined *U. subtilis* as lacking a morphologically specialised holdfast but secreting an adhesive gelatinous layer from the basal cell. The cells in the Yarra River basin material are comparable in size with those found in *U. subtilis* by Lokhorst & Vroman (1972) but sometimes have more than 2 pyrenoids, whereas Lokhorst & Vroman found only 1 or 2. The zoospores in the Yarra River basin plants are also a little larger than those found by Lokhorst & Vroman.

In TJE1328 the chloroplasts were degraded and pyrenoids broken down. An isolate cultured from this collection, however, produced typical *Ulothrix* chloroplast shape and zoospores. Lokhorst & Vroman (1972) reported similar changes in chloroplast morphology in *Ulothrix* species. Other collections from the Yarra River basin may have included similar filaments not recognizable as *Ulothrix*. These may have been included with a dominant mixed species such as *Klebsormidium rivulare*, or grouped with Ulotrichaceae indet. (see above).

Ulvaceae Lamouroux ex Dumortier 1822: 72, 102. Womersley 1984: 135.

Remarks. Only one genus of this family is represented in the Yarra River basin.

Enteromorpha Link 1820: 5 (nom. cons.). Womersley 1984: 151.

Thallus branched or unbranched, tubular or compressed sheet; chloroplasts one per cell, parietal, laminate or cup-shaped, with 1–4 pyrenoids.

Enteromorpha aff. **prolifera** (O.F. Müller) J. Agardh 1883: 129. Koeman & van den Hoek 1982: 118, figs 34–38, 41. Womersley 1984: 156, figs 48D, 49H.

Distribution. Cosmopolitan, freshwater and marine; Yarra River basin (Fig. 13J).

Specimen examined. Site 13: TJE1436.

Plant bright green, probably filiform to tubular when young, finally becoming a ruffled compressed sheet, 300 mm long, 50 mm wide and about 50 µm thick; thallus appears distromatic but the two layers can be separated (best seen under a dissecting microscope); cells mostly in curved short rows or groups of 4–8 but sometimes irregularly arranged; cells quadrilateral in surface view, variously shaped, closely packed, 7–20 µm long, 5–10 µm in diameter, L/D 1–3; chloroplasts laminate, spherical to oval, covering outer periphery of cell, with 1(–2) large pyrenoid(s).

Habitat and phenology. One unattached plant was found twisted around a rock in late spring; water temperature was 21°C. The lower Merri Creek is eutrophic with high pH and conductivity (Victoria, EPA 1983).

Taxonomic remarks. The Merri Creek plant is tentatively referred to *E. prolifera*. The membranous fragment found has a similar cell arrangement and morphology to plants found in the Korkuperrimul Creek at Bacchus Marsh, in the Werribee River basin (MELU 24001, TJE1505, TJE1506). The Korkuperrimul Creek plants are referable to *E. prolifera* on the basis of cell shape and arrangement, chloroplast position in cell (i.e. not forming an apical cap), pyrenoid number and branching pattern. The Korkuperrimul Creek plants change with growth, from profusely-branched and filiform (with cells usually in longitudinal rows) to large, little-branched, membranous sheets (with some small filiform secondary branches sometimes remaining). The Merri Creek fragment may be part of a mature plant of the same species. An unidentified *Enteromorpha* species has been found in Edgars Creek, a tributary of Merri Creek (J. Saunders, EPA, pers. comm.), and the present fragment may have been dislodged from plants farther upstream.

The plants from Merri and Korkuperrimul Creeks resemble species of *Ulva* (not known from fresh water) in having two adnate layers in the sheetlike thallus. *Monostroma* also includes plants with a membranous thallus, which in that genus, however, is monostromatic. *Monostroma expansa* West (in Hardy 1906) was originally described from a pool at Burnley, near the Yarra River, and later found also in the Werribee River (Hardy 1938). Although the syntypes are fragmentary (Entwisle 1989a, fig. 1b) and the cell arrangement and shape are not unlike those in *Enteromorpha prolifera*, the thallus is clearly monostromatic and not consisting of two closely adhering layers.

Zygnemataceae Kützing 1843: 173, 274.

Filaments unbranched; chloroplasts, if parietal, ribbon-shaped and often spiralled, or if axial, plate-like or globose to stellate and in pairs; pyrenoids large and prominent. Reproduction by conjugation.

Taxonomic remarks. The delineation of genera within subfamilies is based on features of the reproductive structures, such as zygospore wall structure and the presence or absence of a conjugation tube. Where reproductive material was not available in the present study, groups of pop-

Key to subfamilies of Zygnemataceae

1. Chloroplasts axial, globose to stellate, two per cell ....Zygnemoideae
— Chloroplasts elongate, one or many per cell, extending through most of cell 2
2. Chloroplasts axial and laminate, usually one per cell .... Mougeotioideae
— Chloroplasts one or more, thin, spiral or longitudinal ribbons .... Spirogyroideae

ulations have been delimited. These groups are given no formal taxonomic recognition (even as "organ" or "form" species; Greuter et al. 1988), because a series of worldwide vegetative taxa (probably necessarily based on overlapping characters) in parallel with the species based on fertile material would eventually confuse rather than enhance the classification of the Zygnemataceae. As with the Oedogoniaceae, the groupings are derived from practical disjunctions in the populations examined. There is no evidence that the groups found in the Yarra River basin include the same species as those found, for example, by Israelson (1949) in Sweden. It seems more useful to apply a local informal name to facilitate ecological studies in each geographical region.

Mougeotioideae Randhawa ex Entwisle subf. nov.

Mougeotioideae Randhawa 1959: 25 (nom. nud.).

Type genus. Mougeotia C. Agardh.

Cells with axial, planar, subrectangular chloroplast(s), generally with pyrenoids, rotating around central long axis in response to light.

Cellulae chloroplast-o(-is) axiali, plano, subrectangulari plerumque pyrenoidibus, qui circum axem longem rotatur.

Remarks. A Latin diagnosis is provided here to legitimise the name proposed by Randhawa (1959). The circumscription of this subfamily is similar to that proposed for the genus *Mougeotia* by Czurda (1932: 56) and for the subfamily Mesocarpoideae West (1916: 325). The name Mesocarpoideae is invalid, however, because it is based on *Mesocarpus* Hassall, a superfluous name for *Mougeotia* (for the interpretation of the IBCN in a similar case, see Silva 1979: 34).

Most species in the subfamily are included in *Mougeotia.*

Mougeotioideae (Slender-Filament Group)

Distribution in Yarra River basin. Fig. 14A.

Specimens examined. Site 26: TJE1298 p.p.; site 45: TJE1367; site 47: TJE905; site 50: TJE1160; site 54: TJE1168; site 108: TJE1376; site 115: TJE1387, TJE1388.

Cells 7–15 µm in diameter, 35–140 µm long, L/D 3.5–20; chloroplast single, sometimes constricted in middle (at nucleus), usually with 3–4 large pyrenoids.

Habitat and phenology. Plants were found on rocks in autumn, winter and spring; water temperature was 9–15°C. All sites are in the relatively pristine upper Yarra and Watts catchments.

Taxonomic remarks. This group is similar to *Mougeotia* a of Israelson (1949: 330).

Mougeotioideae (Broad-Filament Group)

Distribution in Yarra River basin. Fig. 14B.

Specimens examined. Site 11: TJE825; site 26: TJE1298 p.p.; site 28: TJE1323; site 61: TJE948; site 79: TJE1218; site 103: TJE1395; site 106: TJE1402; site 117: TJE1411.

Cells 15–20 µm in diameter, 44–144(–260) µm long, L/D 2.3–9(–14); chloroplast single, usually with 4–6 large pyrenoids.

Habitat and phenology. Plants were found in autumn, winter and spring; water temperature was 7–20°C. This group was found in similar habitats to the Slender-Filament Group but was also present in a few sites that were more eutrophic.

Key to vegetative groups of Mougeotioideae

1. Cells < 15 µm in diameter .... Slender-Filament Group
— Cells > 15 µm in diameter .... Broad-Filament Group

Taxonomic remarks. This group is similar to *Mougeotia* b of Israelson (1949: 330).

Spirogyroideae West 1916: 347. Randhawa 1959: 26.

Cells with one or more parietal, ribbon-shaped (with wavy margin), parallel, slightly curved or spiral chloroplasts around periphery; pyrenoids many, nucleus central in cell.

Spirogyroideae (Squat-Cell Group)

Distribution in Yarra River basin. Fig. 14D.

Specimens examined. Site 18: TJE837; site 16: TJE1090, TJE1122; site 26: TJE857, TJE1105, TJE1213, TJE1420, TJE1439; site 62: TJE950, TJE1195; site 78: TJE990, TJE1107 p.p.; site 79: TJE998, TJE999, TJE1000; site 83: TJE993 p.p., TJE1034, TJE1116, TJE1342, TJE1426, TJE1446.

Cells 40–52 µm in diameter, 16–56 µm long, L/D 0.4–1.3(–2.0), with single chloroplast; septa planar; rhizoids not seen.

Habitat and phenology. Plants were found in spring, summer and autumn; water temperature was 10-17°C. Most habitats are well-lit, little-polluted stretches of the Yarra River and tributaries.

Taxonomic remarks. This group is similar to that described as *Spirogyra* b by Israelson (1949: 343). It is also similar to *S. varians* as described below, and most specimens are probably referable to that species. Some specimens of the Squat-Cell and Elongate-Cell groups may represent plants of the same species at different ages.

Spirogyroideae (Elongate-Cell Group)

Distribution in Yarra River basin. Fig. 14E.

Specimens examined. Site 18: TJE1126; site 19: TJE1132; site 23: TJE1094; site 25: TJE1149, TJE1189; site 26: TJE1056, TJE1281, TJE1317, TJE1438; site 28: TJE1054, TJE1102, TJE1211, TJE1277, TJE1295, TJE1324, TJE1329, TJE1417, TJE1437; site 31: TJE1212; site 56: TJE1078; site 78: TJE1062, TJE1107 p.p., TJE1285, TJE1443; site 83: TJE993 p.p., TJE1224, TJE1289.

Cells 40–50 µm in diameter, 50–250 µm long, L/D 1–5, with 3–4(–6) chloroplasts; septa planar; rhizoids and holdfasts often present.

Habitat and phenology. Plants were found throughout the year but most commonly in autumn; water temperature was 7–18°C. This group has a distribution in the Yarra River basin similar to that of the Squat-Cell Group except that it is also found in the polluted Gardiner's Creek.

Taxonomic remarks. This group is similar to *Spirogyra* e described by Israelson (1949: 344), and like that group most members are probably referable to *S. fluviatilis* Hilse.

Spirogyroideae (Medium-Filament Group)

Distribution in Yarra River basin. Fig. 14F.

Specimens examined. Site 4: TJE1087; site 7: TJE1089; site 14: TJE1135; site 17: TJE1372; site 21: TJE1145; site 43: TJE1256; site 44: TJE1241; site 100: TJE1273 p.p.

Cells 64–100 µm in diameter, 24–280 µm long, L/D 0.3–3.5, often slightly barrel-shaped, with (3–)7–8 chloroplasts; septa planar; rhizoids not seen.

Habitat and phenology. Plants were found in autumn and spring; water temperature was 11–14°C. Habitats are diverse but mostly streams with some eutrophication.

Key to species and vegetative groups of Spirogyroideae

1.	Plants conjugating, zygospores produced	2
—	Plants vegetative only, conjugating cells lacking	3
2.	Zygospores lenticular, > 55 µm long	*Spirogyra submaxima*
—	Zygospores ellipsoid, < 55 µm long	*Spirogyra varians*
3.	Septa replicate (i.e. with circular infold on secondary walls)	Replicate-Septum Group
—	Septa planar	4
4.	Filaments < 60 µm in diameter	5
—	Filaments > 60 µm in diameter	7
5.	Filaments < 30 µm in diameter	Slender-Filament Group
—	Filaments > 30 µm in diameter	6
6.	One chloroplast per cell; cell L/D generally < 1	Squat-Cell Group
—	More than one chloroplast per cell; cell L/D > 1	Elongate-Cell Group
7.	Filaments < 100 µm in diameter	Medium-Filament Group
—	Filaments > 100 µm in diameter	Broad-Filament Group

Taxonomic remarks. Two populations, TJE1145 and part of TJE1273, had only 3 chloroplasts rather than 7–8 as in all other populations. Those plants with many chloroplasts are similar to *Spirogyra* d described by Israelson (1949: 348). Some are also probably referable to *S. submaxima* as described below.

Spirogyroideae (Replicate-Septum Group)

Distribution in Yarra River basin. Fig. 14G.

Specimens examined. Site 27: TJE1333; site 31: TJE870.

Cells 25–35 µm in diameter, 70–230 µm long, L/D 3–8, with 1 chloroplast; septa replicate (with circular infolds of secondary walls); rhizoids not seen.

Habitat and phenology. Plants were found in winter and spring; water temperature was 7–15°C. Both sites are in well-lit stretches of water in the Upper Yarra region.

Spirogyroideae (Broad-Filament Group)

Distribution in Yarra River basin. Fig. 14G.

Specimen examined. Site 48: TJE906.

Cells about 160 µm in diameter, 176 µm long, L/D 1.1, with 7–11 chloroplasts; septa planar; rhizoids not seen (plants free-floating).

Habitat and phenology. Plants were found in spring; water temperature was 15°C. These plants may be more typical of lotic than lentic environments.

Taxonomic remarks. This group is similar to *Spirogyra* e described by Israelson (1949: 349) and also to *S. maxima* but reproductive material is needed to confirm its identity.

Spirogyroideae (Slender-Filament Group)

Distribution in Yarra River basin. Fig. 14G.

Specimen examined. Site 100: TJE1273 p.p.

Cells 24–28 µm in diameter, 28–72 µm long, L/D 1–3, with 1 chloroplast; septa planar; rhizoids not seen.

Habitat and phenology. Plants were only found in the lower Yarra River in autumn.

Taxonomic remarks. This group is similar to *Spirogyra* a described by Israelson (1949: 343).

Spirogyra Link 1820: 5 (nom. cons.). Transeau 1951: 11, 123.

Chloroplast usually spiral, one or more per cell. Conjugating tube present, formed by one or both gametangia.

Remarks. Spirogyra includes most of the described species in Spirogyroideae.

Spirogyra submaxima Transeau 1914: 295, pl. 27, figs 3–4; 1951: 191. Randhawa 1959: 345, fig. 349. Gauthier-Lièvre 1965: 158, pl. 57, fig. B. Kadłubowska 1984: 325, fig. 508.

Distribution. Asia, Africa, America; Yarra River basin (Fig. 14C).

Specimen examined. Site 44: TJE1316.

Cells 68–100 µm in diameter, 110–280 µm long, L/D 1.5–3.5, with 7–9 chloroplasts; septa planar. Conjugation scalariform (involving entire filament), tubes formed by both gametangia; spore-bearing cells inflated; zygospores lenticular (elliptical or circular in optical cross-section), smooth-walled, brown, (56–)72–80 µm in diameter in circular cross-section, 52–55 µm in diameter in elliptical cross-section.

Habitat and phenology. Plants were found in autumn; water temperature was 9°C. See Spirogyroideae (Medium-Filament Group) for habitat details.

Taxonomic remarks. These plants are concordant with those described in the protologue of *S. submaxima*. Hoshaw et al. (1987) found that a "species complex" of *S. maxima* (Hassall) Kützing had a large range in vegetative cell diameters (106–192 µm), and concluded that *S. maxima* and *S. submaxima* may not be distinct species. Nevertheless, the Yarra River basin populations have thinner filaments and are tentatively retained in *S. submaxima* until species concepts in *Spirogyra* are clarified. Hoshaw et al. (1987) also pointed out that under scanning electron microscopy the mesospore wall in *S. submaxima* is pitted like that of *S. maxima*, but in the present study only light microscopy was used and the outer wall appeared smooth.

Spirogyra varians (Hassall) Kützing 1849: 439. Transeau 1951: 153, pl. 22, fig. 1. Randhawa 1959: 297, fig. 256. Gauthier-Lievre 1965: 163, pl. 61, figs Aa-a". Kadłubowska 1984: 288, fig. 443.

Distribution. Cosmopolitan; Yarra River basin (Fig. 14C).

Specimens examined. Site 79: TJE1048; site 83: TJE1034, TJE1347.

Cells 32–45 μm in diameter, 16–72 μm long, L/D 0.5–2.0, sometimes swollen, with 1 chloroplast; septa planar; rhizoids sometimes present. Conjugation scalariform, tubes formed by both gametangia; spore-bearing cells usually inflated on conjugating side; zygospores ellipsoid, smooth walled, yellow, 28–32 μm in diameter, 44–52 μm long, L/D 1.2–1.8.

Habitat and phenology. Plants were found in spring and summer; water temperature was 7–15°C. All habitats are in the Yarra River near Warburton (see also Spirogyroideae (Squat-Cell Group) distribution).

Taxonomic remarks. The plants from the Yarra River basin are similar to those described by Transeau (1951). All have ellipsoid zygospores borne in cells inflated on the conjugation side, a single chloroplast per cell, and similar general dimensions of filaments and zygospores.

The confusing use of the term "ovoid" by Transeau (1951) and Randhawa (1959) to mean "watermelon shaped" rather than "egg shaped" should be noted. The term "ellipsoid" was restricted by Transeau to the meaning "American football shaped" but is used here for any surface whose plane sections are ellipses or circles.

Zygnemoideae. West 1916: 343. Randhawa 1959: 26.

Cells with more than 1 (usually 2) axial, globose to stellate chloroplasts, sometimes with irregular processes; 1 large pyrenoid per chloroplast.

Taxonomic remarks. Zygnemoideae includes the type genus of the family Zygnemataceae and is therefore an autonym (requiring no authority). Most species are included in the genus *Zygnema*.

Zygnemoideae (Vegetative Group)

Distribution in Yarra River basin. Fig. 14H.

Specimens examined. Site 4: TJE814; site 8: TJE806, TJE809; site 28: TJE1323; site 50: TJE914, TJE1158, TJE1160; site 51: TJE1163; site 117: TJE1411.

Cells 18–28 μm in diameter, 16–64 μm long, L/D 0.9–2.2; with two axial chloroplasts, globular or stellate (with radiating processes).

Habitat and phenology. Plants were found in autumn, winter and spring; water temperature was 7–13°C. Representatives are distributed widely around the catchment but are not generally common. Most sites are oligotrophic but the genus can apparently withstand some eutrophication (e.g. TJE814 in lower Diamond Creek).

Taxonomic remarks. This group is similar to *Zygnema* a and *Zygnema* b of Israelson (1949: 338, 340).

Chrysophyta

Chrysocapsaceae Pascher 1912: 175, 198.

Remarks. This family is represented in the Yarra River basin by only one macroalgal genus.

Tetrasporopsis (De Toni) Lemmermann 1899: 103. Schmidle 1902: 158. Bourrelly 1968: 64.

Plants consisting of a rubbery sac adhering at base to substratum (e.g. tree roots); cells in an outer layer of homogeneous, gelatinous matrix; chloroplasts golden-brown, parietal, 2–4 per cell.

Tetrasporopsis fuscescens (A. Braun ex Kützing) Lemmermann 1899: 103. Schmidle 1902: 159.

Distribution. Europe; Yarra River basin (Fig. 141).

Specimens examined. Site 42: TJE896, TJE1357; site 53: TJE922.

Plants cumulous, yellow to brown, to 20 mm in diameter; cells enclosed singly or in pairs, in mucilage 1–2 μm thick, closely packed; cells walled, spherical, 5–11 μm in diameter, with 2–4 cup-shaped chloroplasts; pyrenoids and contractile vacuoles absent. Reproduction unknown.

Habitat and phenology. Plants were found in spring only; water temperature was 10–11°C. The streams were surrounded by farmland.

Taxonomic remarks. The morphology and arrangement of cells in the thallus correlates well with the plants described as *T. fuscescens* by Tschermack-Woess (1980). There has been some dispute in the literature over whether *Tetrasporopis* has cell walls but Dr R. Andersen (pers. comm.) has recently discovered that the type material of *T. fuscescens* does have walled cells, supporting the conclusions of Tschermack-Woess (1980).

Tetrasporopsis is similar macroscopically to *Palmellopsis* and *Tetraspora* (Chlorophyta) but the thallus is more rubbery, the cells are more densely packed and arranged in an outer layer rather than throughout the thallus, and the plant is brown rather than grass-green.

As pointed out by Lund (1960) and Bourrelly (1968), the lack of knowledge about motile spores in this, the type species of the genus, makes affinities uncertain. No spores were found in the present study.

Tribonemataceae Pascher 1912: 18 (as Tribonemaceae).

Remarks. Only one genus of this family was found in the Yarra River basin.

Tribonema Derbes & Solier in Castagne 1851: 96. Smith 1950: 397. Ettl 1978: 438. Bold & Wynne 1985: 435.

Plants consisting of unbranched uniseriate filaments, with oil rather than starch as a storage product; cells with L/D generally greater than 2; chloroplast single to many, discoid, yellow-green, usually with no pyrenoid. Cells breaking into H-shaped pieces to release zoospores or isogametes.

Tribonema minus (Wille) Hazen 1902: 185, pl. 25, figs 7, 8. Starmach 1968: 334, fig. 472. Ettl 1978: 449, fig. 553.

Distribution. Cosmopolitan; Yarra River basin.

Specimens examined. Site 26: TJE1298; site 83: TJE1322.

Cells cylindrical or very slightly constricted at septa, 5.5–8 μm in diameter, 18–26 μm long, L/D 2.5–4.5; cell walls thin with no distinct H-shaped wall pieces; chloroplasts parietal, discoid, 2 wrapped laterally around cell, sometimes attached in middle, with no pyrenoids. Zoosporangia not seen.

Habitat and phenology. Plants were found in winter; water temperature was 7–10°C. Both sites are in the Yarra River near Warburton but this species is probably more widespread in lotic or semi-terrestrial environments.

Taxonomic remarks. Tribonema minus is distinguished from the other species of the genus in having two chloroplasts in relatively squat cells less than 10 μm in diameter (Ettl 1978, Hazen 1902).

Vaucheriaceae S.F. Gray 1821: 288 (as Vaucherideae; corr. Dumortier 1822).

Remarks. Only one genus of this family was found aquatically in the Yarra River basin.

Vaucheria de Candolle 1801: 20. Entwisle 1988: 12.

Distribution in Yarra River basin. Fig. 14J.

Plants consisting of aseptate, branched siphons tangled in a mat, sometimes with short erect portions; chloroplasts discoid, numerous in peripheral cytoplasm. Sexual reproduction by fusion of sperm (from usually tubular male gametangium) with oogonium; oospore usually with resistant wall.

Remarks. Only plants growing in flowing water are considered here, although the same populations will commonly be emergent for some part of the season. For descriptions and keys to terrestrial species, as well as full descriptions of the species recorded in the present study, see Entwisle (1988; note that most of the records from the Yarra River basin in that publication are not fully aquatic). All plants were sterile when collected (as is usual for *Vaucheria* in flowing water) but many produced gametangia in a "crude" culture (i.e. kept moist in a petri-dish).

Habitat and phenology. Vaucheria spp. are found in slightly polluted streams and rivers. Although the genus is widely distributed on muddy banks where there is some nutrient input, it tends not to occur aquatically in highly polluted urban creeks. If it is found in large mats in flowing water it is generally indicative of an "intermediate" level of eutrophication. It grows in slow-flowing, shallow water habitats in the Yarra River from Dight's Falls to Warburton. In urban creeks dominated by *Cladophora* and *Stigeoclonium* it is usually not found aquatically.

Key to species of *Vaucheria*

1.	Oogonia sessile on vegetative siphon	2
—	Oogonia and male gametangia terminal on lateral, bisexual siphon (gametophore)	3
2.	Male gametangia circinate, on short pedicel	*V. bursata*
—	Male gametangia mostly straight, not pedicellate	*V. aversa*
3.	Oogonia erect (directed away from vegetative siphon)	*V. geminata*
—	Oogonia pendent	4
4.	Oogonia almost radially symmetrical around oogonial pedicel, with no distal prominence	*V. uncinata*
—	Oogonia bilaterally symmetrical, with distal prominence	*V. prona*

Presumably it cannot tolerate extreme eutrophication (perhaps toxic metals rather than high nutrient levels) but requires a substantial input of nutrients for growth. The distribution of *Vaucheria* is closely linked with agricultural land use, particularly in Diamond Creek (Consulting Environmental Engineers 1986).

Vaucheria aversa Hassall 1843: 429. Entwisle 1988: 57, figs 105–108.

Distribution. Cosmopolitan; Yarra River basin (Fig. 15B).

Specimens examined. Site 26: TJE1346.

Oogonia globose, with apex reflexed towards siphon; oospores globose to ellipsoid, leaving distal and peripheral oogonial cavity when mature. Male gametangia reflexed at base, orientated parallel to siphon, fusiform to cylindrical.

Habitat and phenology. Plants were found in winter; water temperature was 8°C. *V. aversa* is relatively common in mountain areas of Victoria (Entwisle 1988) but is not usually fully aquatic.

Vaucheria bursata (O.F. Müller) C. Agardh 1811: 21. Entwisle 1988: 14, figs 6–14.

Distribution. Cosmopolitan; Yarra River basin (Fig. 15A).

Specimens examined. Site 11: TJE872; site 17: TJE1125; site 22: TJE936; site 37: TJE1190, TJE1278; site 42: TJE940; site 78: TJE1345; site 83: TJE1050, TJE1067, TJE1359; site 91: TJE1406; site 101: TJE1365.

Oogonia ovoid to ovoid-reniform, usually sessile on siphon; oogonial walls smooth; oospore walls evenly textured. Male gametangia pedicellate, less than 100 µm long, turning through less than a full circle and similar in size and shape throughout the plant.

Habitat and phenology. This is the most common *Vaucheria* species throughout the year in the Yarra River basin; water temperature was 7–18°C. Fjerdingstad (1965) stated that *V. bursata* is capable of thriving in polluted water but is generally found in other than polluted habitats. Like *Cladophora glomerata*, it grows naturally in streams that are more alkaline than those in the upper Yarra catchment. Nevertheless, the species is widespread in the upper and middle Yarra regions.

Vaucheria geminata (Vaucher) de Candolle in Lamarck & de Candolle 1805: 62. Entwisle 1988: 41, figs 66–71.

Distribution. Cosmopolitan; not common in Victoria; Yarra River basin (Fig. 15B).

Specimen examined. Site 15: TJE831.

Gametophores with erect oogonia borne on almost straight oogonial pedicels making an acute angle with peduncle. Male gametangia monoporic, borne on erect pedicels which are curved only distally.

Habitat and phenology. Plants were found in spring; water temperature was 11°C. They were found in a clean mountain stream (Ca 16.8 mg/L, Mg 1.2 mg/L) similar to the previously recorded habitats of *V. geminata* in Victoria (Entwisle 1988).

Taxonomic remarks. The population studied had gametophores with 2–3 oogonia and supports the synonymy of *V. taylorii* and *V. geminata* proposed by Entwisle (1988). The name *V. geminata* is used in the absence of any clearly defined taxon that has erect oogonia and can be distinguished from *V. taylorii* and the plants found in the present study.

Vaucheria prona Christensen 1970: 250, figs 1, 2. Entwisle 1988: 48, figs 82–90.

Distribution. Cosmopolitan; Yarra River basin (Fig. 15B).

Specimens examined. Site 17: TJE1125; site 22: TJE936, TJE1194.

Gametophores with 1 or more, usually pendent, oogonia less than 100 µm long (if only 1 oogonium, it is lateral to antheridium); oospore walls less than 5 µm thick and evenly textured; oogonia with no oogonial cavity left by mature oospore.

Habitat and phenology. Plants were found in autumn and spring; water temperature was 12–13°C. *V. prona* is a common species on moist soil (Entwisle 1988) but was found aquatically at only two sites in the Silvan Reservoir area.

Vaucheria uncinata Kützing 1856: 21, pl. 60, fig. 1. Entwisle 1988: 53, figs 101–104.

Distribution. Cosmopolitan; to date known in Victoria only from the Yarra River basin (Fig. 15B).

Specimens examined. Site 16: TJE840, TJE891; site 24: TJE1255; site 26: TJE1023, TJE1059; site 78: TJE1021.

Gametophores with radially symmetrical, pendent oogonia more than 100 µm long and with no distal prominence; mature oospore green, without thick protective wall.

Habitat and phenology. V. uncinata is restricted to aquatic environments in Australia, occurring in spring, summer and early autumn; water temperature was 11–18°C. The species does not grow in the Yarra River below Yarra Glen.

Vaucheria sp. (sterile)

Specimens examined. (Excluding any from sites where at least one species determination has been made.) Site 3: TJE1085; site 4: TJE808; site 7: TJE811; site 16: TJE839; site 20: TJE842; site 43: TJE897; site 69: TJE964; site 89: TJE1038, TJE1040; site 96: TJE1267; site 98: TJE1270; site 100: TJE1273, TJE1275.

Cyanophyta (Cyanobacteria)

The taxonomic treatment of this group used here is mainly that specified by Drouet (1981), accompanied where possible by reference to classically defined taxa (eg. Desikachary 1959). Although there are faults in Drouet's system, the ideal of reducing the number of taxa in a group showing such phenotypic plasticity is admirable. Most of the arguments put forward by Drouet are logical and his exhaustive study of herbarium material establishes him as a formidable authority. While there is ample evidence to suggest that genetically stable entities with narrow genetic variation do exist (Anagnostidis & Komárek 1985), the point at issue is whether taxonomically useful disjunctions exist between such narrowly defined taxa.

K. K. Baker (1987) recently proposed a more classical treatment, based on Geitler (1932), with additional undescribed, numbered taxa. She found that this system showed the "highest resolution and consistency" of any when applied to the phenetic clusters delineated in her study. Her system is not a comprehensive treatment of the Cyanophyta, however, and leaves many of the more difficult problems of taxon delineation unsolved. A. F. Baker & Bold (1970) had earlier proposed an expanded system based on that of Drouet but the many varieties they described are essentially similar to the ill-defined species of earlier authors.

The system of Rippka et al. (1979) aimed to rationalize the number of taxa recognised, but did not extend to species level and included the nomenclaturally meaningless group "LPP". In addition, although the unsuitability of sheath characteristics in defining taxa is stressed, these features are used to delineate the LPP group (Broady, Garrick & Anderson 1984). The motility/immotility of trichomes is considered to be an important generic character but was not recorded in most of the collections from the Yarra River basin. For these reasons, the "Rippka" system has not been used here.

The recent proposals by Anagnostidis & Komárek (1988) for the Oscillatoriales have taken into account much of the new experimental data. While they present a complete classification at family level, the circumscription of genera is still somewhat nebulous and the delineation of species is not considered. The full development of this approach may eventully provide some middle ground for cyanophyte taxonomy.

The use of bacteriological features (mainly physiological characteristics of cultured plants) to define taxa further complicates the taxonomy of the Cyanophyta. In the current study, the plants collected were in macroscopic colonies, similar in habit and habitat to other algae. It thus seems practical and efficient to include them in this survey, and to define taxa on the basis of morphological characteristics. Humm & Wicks (1980: 6) suggested that until we have a taxonomic system that combines morphology with whatever bacteriological-type characters are needed, "the best we can do is to use Drouet's carefully devised taxonomy plus older names for the ecotypes of ecophenes that have been described in the past. In this way it is possible to indicate which variants of Drouet's 'lumping' we have in mind".

Priority for names begins with Gomont (1892) for the Loefgreniaceae and Oscillatoriaceae, and Bornet & Flahault (1988) for the Nostocaceae (see Greuter et al. 1988). The divisional name Cyanophyta is retained (instead of Cyanobacteria) following the reasoning of Bold & Wynne (1985), and because the International Code of Botanical Nomenclature (Greuter et al. 1988) has been used rather than the bacterial code.

Loefgreniaceae Elenkin 1917: 94.

Remarks. This family includes only one genus.

Loefgrenia Gomont in Wittrock et al. 1897: 89. Bourrelly 1985: 383.

A monotypic genus of bright green plants, consisting of erect trichomes attached to rocks at base by mucilage (Fig. 3D); trichomes without sheath, gradually tapering to mucronate apex in mature plants; sometimes with colourless apical cell(s) (Fig. 3A); basal cell with parabolic to conical distal end (Fig. 3C, D); other cells cylindrical, slightly constricted at septa, variable in length (Fig. 3A, D).

Loefgrenia anomala Gomont in Wittrock et al. 1897: 90, fig. "1350". Prescott et al. 1949: 90, pl. 2, figs 9, 10. Drouet 1981: 183, figs 53–55.

Fig. 3

Distribution. Cosmopolitan; Western Australia; Yarra River basin (Fig. 15C).

Specimens examined. Site 27: TJE1027, TJE1334; site 60: TJE942, TJE1200; site 62: TJE1196; TJE953, TJE1206; site 64: TJE1207; site 74: TJE1187; site 78: TJE984, TJE991, TJE1031, TJE1444; site 83: TJE1065; site 92: TJE1171.

Trichomes unbranched, to 1 mm long; cells cylindrical (Fig. 3A, D), 2–8 µm in diameter, 7–75 µm long, L/D (2–)3–15, with granular cytoplasm; apical cell often colourless and friable (Fig. 3A); mature trichomes tapering gradually towards apex (Fig. 3A), young trichomes with more rounded apex (Fig. 3D). Reproduction by fragmentation into short cylindrical to ellipsoid cells with rounded ends, 7–17 µm long.

Habitat and phenology. Tufts of filaments growing in fast-flowing water were found year round; water temperature was 7–18°C. *L. anomala* is fairly common in mountain creeks and the upper Yarra River. It is restricted to sites with low nitrogen (generally less than 0.83 mg/L, but an isolated reading of 1.78 mg/L) and phosphorus (less than 0.04 mg/L), and with few ions (hardness less than 54.0 mg/L and conductivity less than 108 µS/cm).

Taxonomic remarks. There is some uncertainty about the delineation of this genus and species. Although Drouet (1981) described heterocysts in *L. anomala*, both Gomont (in Wittrock et al. 1896) and Bourrelly (1985) did not find any in the material they examined. Gomont (in Wittrock et al. 1896) found branching of trichomes to be characteristic of the species but Drouet (1981) and Bourrelly (1985; see legend to pl. 104, figs 4–6) found branching to be very rare or absent altogether. The shape, structure and habit of the trichomes, however, are unlike those of most other cyanophytes.

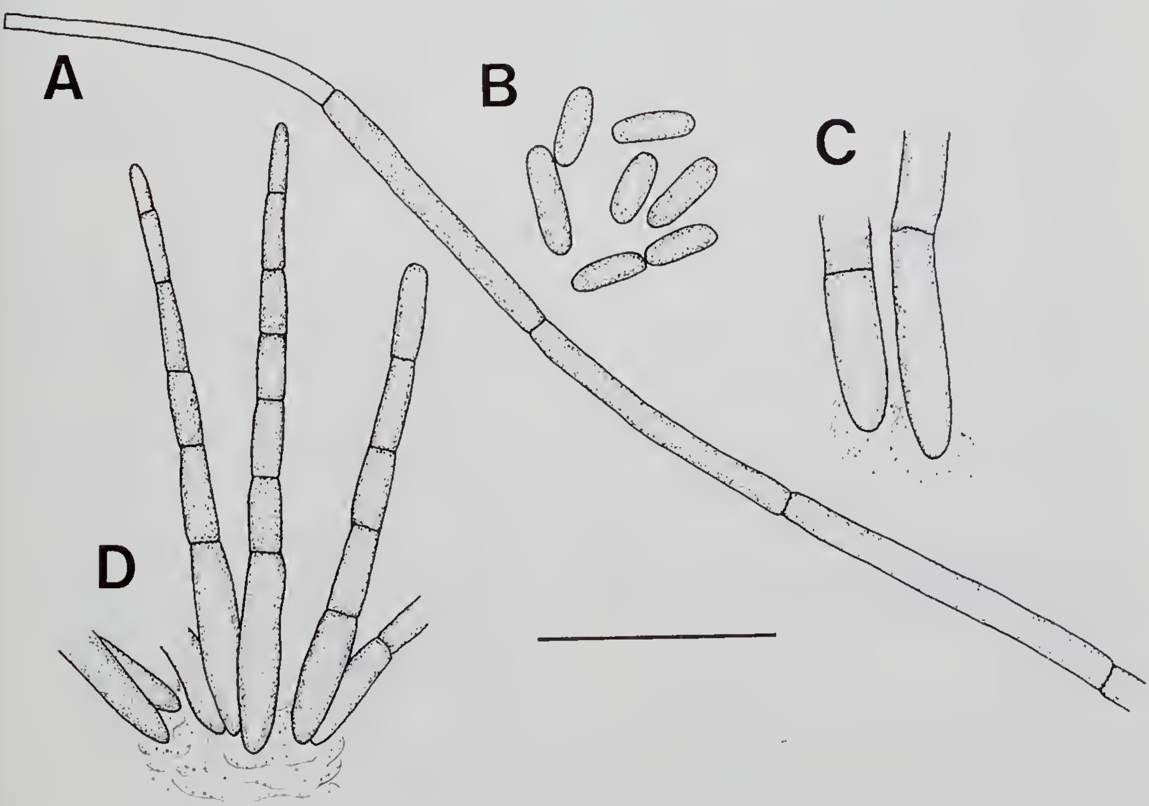


Fig. 3. Loefgrenia anomala Gomont (TJE1031, scale 25 µm). A, Apical portion of trichomes showing long cells and terminal cell without protoplast. B, Fragmentation of trichome into single cells. C, Base of mature trichomes showing slightly broader cells. D, Group of young trichomes attached by base in mucilage.

Loefgrenia was placed in the Nostocaceae by Drouet (1981) and in the Mastigocladaceae by Bourrelly (1985), both of these families being characterised by the presence of heterocysts. Since no heterocysts were found in the Yarra River basin material, the genus is retained in its own family until it becomes better understood.

In spite of the uncertainty over the application of the generic name, the taxon described here is clearly delineated. It can be distinguished from all genera described here in the Oscillatoriaceae by its long cells (L/D greater than 3) and its gradually narrowing trichome attached by mucilage at the base.

Nostocaceae C. Agardh 1824: xv. Drouet 1981: 179.

Plants filamentous and colonial; trichomes capable of forming heterocysts, more or less constricted at cross-walls.

Anabaena Bory de St-Vincent ex Bornet & Flahault 1888: 233. Drouet 1978: 131; 1981: 187.

Heterocysts present; trichomes constricted at cross-walls, mature terminal cell generally conical.

Anabaena oscillarioides Bory de St-Vincent ex Bornet & Flahault 1888: 233. Drouet 1978: 156, 181, figs 32–42; 1981: 187, figs 69–72.

Distribution. Cosmopolitan; Yarra River basin (Fig. 15E).

Specimen examined. Site 32: TJE1074 p.p.

Plants forming amorphous mat; trichomes with generally intercalary, ellipsoid to cylindrical heterocysts; heterocysts with rounded ends, 5–6 μm in diameter, 7–8 μm long; vegetative cells cylindrical-discoid with rounded ends, separated by deep incisions at septa, 4–6 μm in diameter, 2–5 μm long, L/D 0.5–1; terminal cells initially globular to hemispherical, finally obtuse-conical; akinetes common, cylindrical with rounded ends, very granular contents, 5–7 μm diameter, 11–17 μm long, formed singly or in pairs.

Habitat and phenology. Plants were found in autumn; water temperature was 19°C. *A. oscillarioides* is perhaps typical of lotic environments, being found in slow-flowing water behind a weir in the Plenty River.

Taxonomic remarks. The terminal cell is often "thimble-shaped" or hemispherical, making generic determination difficult. In Drouet's system, *Nostoc commune* Vaucher ex Bornet & Flahault is similar to *Anabaena oscillarioides* except that it has almost spherical terminal cells. The most closely-matching species in Desikachary's (1959) monograph is *A. laxa* (Rabenhorst) A. Braun ex Bornet & Flahault, which Drouet (1978) regarded as a synonym of *A. oscillarioides*.

Scytonema C. Agardh ex Bornet & Flahault 1888: 82, 85. Drouet 1981: 180.

Plants tufty, branched (Fig. 4C); sheaths consisting of more than one trichome (Fig. 4B); heterocysts present (Fig. 4A, B) or absent; apical cell of trichome hemispherical to spherical (Fig. 4D).

Scytonema hofmannii C. Agardh ex Bornet & Flahault 1888: 97. Drouet 1981: 180, figs 43, 44.

Fig. 4

Ecophene. Coleodesmium wrangelii (C. Agardh) Borzi (see Bourrelly 1985: 394, pl. 108, figs 1–3).

Distribution. Cosmopolitan; Yarra River basin (Fig. 15D).

Specimens examined. Site 16: TJE1091, TJE1152; site 26: TJE989; site 34: TJE878; site 36: TJE883; site 45: TJE902, TJE1367, TJE1368, TJE1431; site 60: TJE943, TJE944, TJE1202; site 63: TJE1204; site 64: TJE955; site 65: TJE958; site 70: TJE965, TJE966, TJE967, TJE1182; site 71: TJE968; site 73: TJE972; site 78: TJE983, TJE1110, TJE1340, TJE1353, TJE1423; site 83: TJE994, TJE1114; site 98: TJE1271.

Plant tufty (Fig. 4C) (like *Audouinella* macroscopically), in mats to 5 mm high, dark olive-green to brown, consisting of numerous trichomes enclosed in a common branched sheath, 25–85 μm in diameter.

Key to genera of Nostocaceae

1. Trichomes deeply constricted at cross-walls; trichomes irregularly arranged in mucilaginous mat .... *Anabaena*

— Trichomes little or not constricted at cross-walls; plants tufty, branched .... *Scytonema*

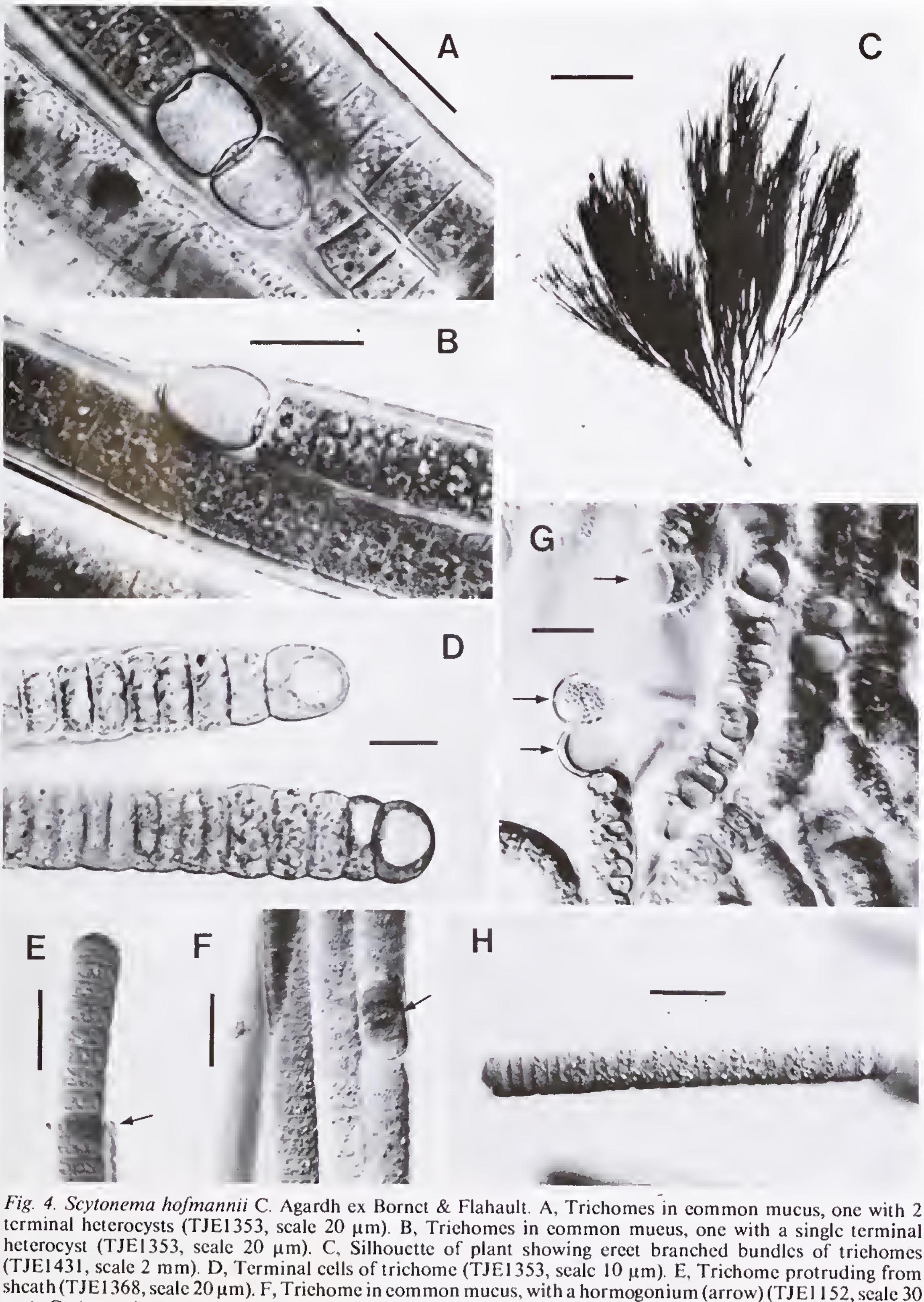


Fig. 4. Scytonema hofmannii C. Agardh ex Bornet & Flahault. A, Trichomes in common mucus, one with 2 terminal heterocysts (TJE1353, scale 20 μm). B, Trichomes in common mucus, one with a single terminal heterocyst (TJE1353, scale 20 μm). C, Silhouette of plant showing erect branched bundles of trichomes (TJE1431, scale 2 mm). D, Terminal cells of trichome (TJE1353, scale 10 μm). E, Trichome protruding from sheath (TJE1368, scale 20 μm). F, Trichome in common mucus, with a hormogonium (arrow) (TJE1152, scale 30 μm). G, Amorphous arrangement of trichomes in culture, with numerous heterocysts (e.g. arrows) (TJE1368, scale 20 μm). H, Short segment of trichome (TJE1152, scale 30 μm).

Trichomes (Fig. 4E, F) cylindrical to torulose (with slight constrictions at each septum or at alternate ones), straight, curved or less commonly spiralled within sheath; heterocysts absent or present, 1–3, terminal, spherical, ovoid or discoid (Fig. 4A, B, G); cells much shorter than broad (Fig. 4D), 7–17 μm in diameter, 2–6 μm long, L/D 0.2–0.5; cytoplasm usually granulate (Fig. 4F, H), granules sometimes more abundant adjacent to septa but never lining them; terminal cell hemispherical (Fig. 4D), 7–11 μm in diameter, 5–10 μm long, L/D 0.5–1.3; sheath (Fig. 4E) with thick (to 8 μm) outer layer of mucus usually present, translucent or slightly tan coloured, sometimes persisting without trichome.

Hormogonia (Fig. 4F, H) frequently formed by destruction and compression of intercalary cells.

Habitat and phenology. Plants were found year round but were rare in winter; water temperature was 6–19°C. *S. hofmannii* was found in mountain creeks and the Yarra River. Conductivity was low in the Yarra River as far downstream as Dight's Falls (maximum reading of 280 μS/cm in the middle Yarra), in comparison with most lowland tributaries. Phosphorus was less than 0.33 mg/L, averaging about 0.2 mg/L in the lower Yarra but being higher in the neighbouring tributaries. Hardness was up to 83 mg/L, much lower than in most tributaries (up to 1200 mg/L in Northern Creeks). pH reached 7.7 in the lower Yarra but was up to 9.9 in some lowland tributaries (which did not support *S. hofmannii*). Nitrogen and toxicants, however, were similar in both urban creeks and the lower Yarra River.

Scytonema hofmannii seems to grow in streams which are acidic to slightly alkaline and have low levels of cations, but it can tolerate some eutrophication in larger rivers.

Remarks. Scytonema is usually characterised by the presence of heterocysts. Since most collections from the Yarra River basin had no heterocysts, the plants could be referred to the Oscillatoriaceae. In that family, *Schizothrix mexicana* Gomont (as delineated in Drouet 1981) encompasses the range of morphologies described above. However, in culture media without nitrate, and also in depleted full-nutrient media, heterocysts were produced in trichomes isolated from plants that did not bear heterocysts in the field (Fig. 4G). It is presumed, therefore, that the non-heterocyst bearing plants are ecophenes of *Scytonema hofmannii*. The repercussions of this morphological plasticity in terms of familial classification cannot be dealt with here, but a thorough analysis of heterocyst production in the field and in culture is needed for members of the *Scytonema/Schizothrix* complex. Sinclair & Whitton (1977) found a similar variation in heterocyst production in members of the Rivulariaceae; in that family, populations seemed either to have the ability to produce heterocysts, or else would not do so under any conditions. Since at least some Yarra River plants have the potential to produce heterocysts, they are here included in a family and genus characterised by heterocyst formation. *Scytonema hofmannii* also has priority over *Schizothrix mexicana*, should synonymy be demonstrated in the future.

The tufty habit of these plants (Fig. 4C) is unique among the Cyanophyta in the Yarra River basin, and is similar to that described in *Coleodesmium wrangelii* (C. Agardh) Borzi by Bourrelly (1985). Genera with similar habit in the monograph by Desikachary (1959) include *Tolypothrix* and *Plectonema*, heteocysts being present in the former but absent in the latter. *Tolypothrix distorta* Kützing ex Bornet & Flahault in particular resembles the plants with heterocysts described here.

Oscillatoriaceae Engler 1898: 6. Drouet 1968: 14. Silva 1980: 53, 103 (nom. cons.). Drouet 1981: 159.

Trichomes little or not constricted at cross-walls, without heterocysts, amorphously arranged in mats.

Arthrospira Stizenberger ex Gomont 1892: 246. Drouet 1968: 215. Humm & Wicks 1980: 74. Drouet 1981: 174.

Septa lined on both sides with granules (Fig. 5A). Terminal cell without thickened end-wall (Fig. 5A).

Arthrospira jenneri (Hassall) Stizenberger ex Gomont 1892: 247. Drouet 1968: 216, figs 84, 85; 1981: 175, fig. 104.

Fig. 5A

Distribution. Europe, North and South America, Pakistan; Yarra River basin (Fig. 15E).

Specimens examined. Site 10: TJE815 p.p.; site 26: TJE1318; site 32: TJE1074 p.p.; site 43: TJE897 p.p.; site 49: TJE1157; site 62: TJE1197; site 72: TJE1183; site 85: TJE1015.

Key to genera of Oscillatoriaceae

1. Terminal cell or end of trichome acuminate, with apical swelling or thickened end-wall cap 2
— Terminal cell hemispherical, cylindrical or short-conical; end of trichome mostly cylindrical 3
2. Terminal cell long-acuminate . . . . *Porphyrosiphon*
— Terminal cell short-conical, with thickened end-wall cap; terminal portion of trichome tapering . . . . *Microcoleus*
3. Septa lined on both sides by distinct granules . . . . *Arthrospira*
— Septa not lined by granules but irregular granules may be present in cells . . . . *Schizothrix*

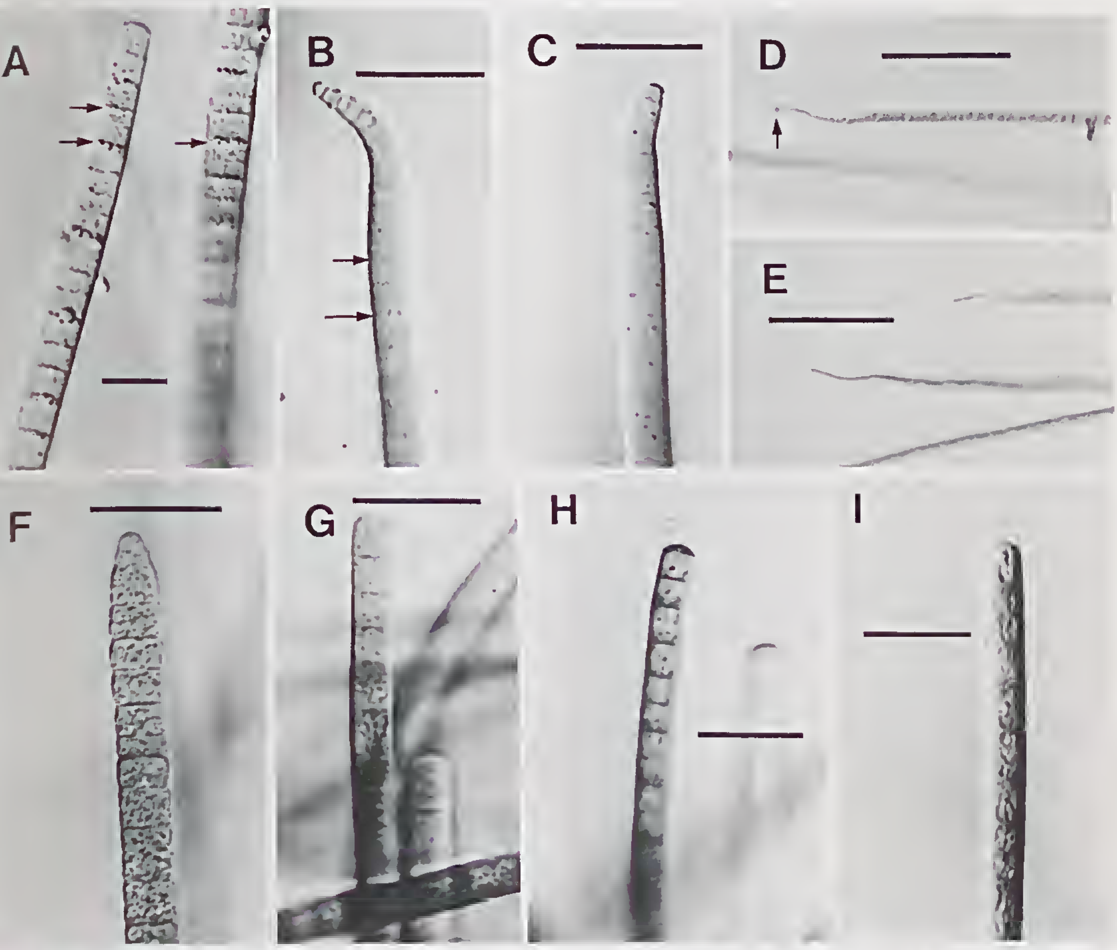


Fig. 5. A, *Arthrospira jenneri* (Hassall) Stizenberger ex Gomont. Trichome with cylindrical terminal cell and granules lining septa (arrows) (TJE1318, scale 10 μm). B, C, *Microcoleus vaginatus* (Vaucher) Gomont ex Gomont. Trichomes with granules lining septa (arrows), attenuated terminal portion and thickened end-wall cap (TJE1360, scale 20 μm). D, E, *Porphyrosiphon splendidus* (Greville ex Gomont) Drouet. Trichomes with long attenuate ends; some have swollen apex (arrow) but no end-wall thickening (TJE892, scale 20 μm). F, *Schizothrix arenaria* (Berkeley) Gomont. Trichome with obtuse-conical apical cell (TJE1071, scale 20 μm). G–I, *Schizothrix friesii* (C. Agardh) Gomont ex Gomont (TJE1030, scale 20 μm). G, Trichome with cylindric apical cell and no obvious sheath. H, Trichome with thin sheath. I, Trichome with sheath barely visible.

Plants forming amorphous blue-green mats; trichomes cylindrical; cells 2–8 μm in diameter, 4.5–6 μm long, L/D 1.3–2.5; septa lined on both sides with granules; terminal cells cylindrical to hemispherical; sheaths absent or present, thin.

Habitat and phenology. Plants were found year round; water temperature was 7–19°C. Although not used as a characteristic species in the ecological classification of sites, *A. jenneri* mostly occupies a specialised niche; ie. lowland streams running through dry schlcrophyll forest (but site 72 in the Watts River, surrounded by "wet forest", is an exception). There was generally some nutrient input into the streams from agriculture.

Taxonomic remarks. Some trichomes seem to have a slight thickening on the terminal cell end-wall. A pronounced thickening is characteristic of *Microcoleus irriguus* (Kützing) Drouet, a species similar in all other respects. Since this thickening was generally absent or insignificant, all plants are referred to *A. jenneri*. The genera *Lyngbya* and *Oscillatoria* have also been circumscribed so as to include similar plants (Desikachary 1959).

Microcoleus Desmazières ex Gomont 1892: 350. Drouet 1968: 224. Humm & Wicks 1980: 79. Drouet 1981: 176.

Septa lined on both sides by granules (Fig. 5B, C); terminal cell with thickened end-wall cap (Fig. 5B, C).

Microcoleus vaginatus (Vaucher) Gomont ex Gomont 1892: 355. Drouet 1968: 226, 244, figs 89–99. Humm & Wicks 1980: 81, fig. 27. Drouet 1981: 177, fig. 105.

Fig. 5B, C

Distribution. Cosmopolitan; Yarra River basin (Fig. 15F).

Specimens examined. Site 4: TJE814; site 16: TJE845; site 23: TJE1095; site 32: TJE875; site 63: TJE952; site 66: TJE959; site 91: TJE1360; site 118: TJE1413.

Plants forming amorphous, blue-green to grey-green mats; trichomes cylindrical; cells 5–7 μm in diameter, 3–5 μm long, L/D 0.5–0.8, with granules lining both sides of septa; apical portion of trichome (first few cells) narrowing; at least some terminal cells hemispherical to conical with outer wall becoming thickened into a cone or cup; sheaths not seen.

Habitat and phenology. Plants were found in spring and autumn; water temperature was 9–18°C. *M. vaginatus* grows in a wide range of habitats in eutrophic and oligotrophic creeks, and in the Yarra River at Warrandyte.

Taxonomic remarks. The description of *M. vaginatus* by Desikachary (1959) applies also to these populations.

Porphyrosiphon Kützing ex Gomont 1892: 331. Drouet 1968: 142; 1981: 167.

Trichomes attenuated at ends (Fig. 5D, E), with no granules or 2 large ones on both sides of septa; outer wall of terminal cell not thickened.

Porphyrosiphon splendidus (Greville ex Gomont) Drouet 1968: 166, fig. 80; 1981: 169, fig. 92.

Fig. 5D, E

Distribution. Cosmopolitan; Yarra River basin (Fig. 15F).

Specimens examined. Site 41: TJE892, TJE1257.

Plants forming amorphous, blue-green mats; trichomes mostly cylindrical; cells mostly 1.5–2.5 μm in diameter, 2–5 μm long, L/D 1–2.5; ends of at least some trichomes attenuate, with ultimate cell long and narrow, up to 20 μm long, less than 1 μm in diameter, slightly swollen apically (Fig. 5D) but without any wall thickening; sheath thin; short truncate portions of trichome form hormogonia.

Habitat and phenology. Plants were found in autumn and spring; water temperature was 10–13°C. *P. splendidus* was only found in creeks to the north of Melbourne. Site 41 in Watsons Creek was dry in summer.

Taxonomic remarks. Desikachary (1959) included this taxon in *Oscillatoria*, as *O. splendida* Greville ex Gomont.

Schizothrix Kützing ex Gomont 1892: 192. Drouet 1968: 26; 1981: 161.

Septa not distinctly lined with granules; terminal cell without wall thickenings; ends of trichomes either not attenuated or with only terminal cell tapering.

Schizothrix arenaria (Berkeley) Gomont 1892: 312. Drouet 1968: 109, 115, figs 28–34; 1981: 164, figs 80–81.

Fig. 5F

Distribution. Cosmopolitan, Yarra River basin (Fig. 15G).

Key to species of ***Schizothrix***

1.	Apical cell conical	*S. arenaria*
—	Apical cell rounded	*S. friesii*

Specimens examined. Site 58: TJE1071; site 82: TJE1222; site 91: TJE1075; site 121: TJE1456.

Plants forming amorphous, blue-green mats; trichomes torulose (Fig. 5F); cells 5–8 μm in diameter, 3–8 μm long, L/D 0.5–1.6, constricted at septa; at least some terminal cells obviously obtuse-conical (Fig. 5F), 8-11 μm long, remainder hemispherical; sheaths present or absent; when present, mucilaginous, to 4 μm thick.

Habitat and phenology. Plants were found in summer and autumn; water temperature was 10–17°C. Most sites were disturbed but none was heavily polluted.

Taxonomic remarks. Microscopically this taxon is similar to *Scytonema hofmannii* except for the presence of some obtuse-conical terminal cells. In TJE1071 very few end cells are conical and the distinction from *S. hofmannii* is often not clear. In all populations, however, the thallus is not tufty and branched as is typical of *S. hofmannii* but is more or less an amorphous mat like that of *Schizothrix friesii*. The plants are similar to some species of *Phormidium* and *Lyngbya* described by Desikachary (1959).

Schizothrix friesii (C. Agardh) Gomont ex Gomont 1892: 316. Drouet 1968: 99, 103, figs 23–27; 1981: 164, figs 78, 79.

Fig. 5G–I

Distribution. Cosmopolitan; Yarra River basin (Fig. 15H).

Specimens examined. Site 10: TJE815 p.p.; site 16: TJE1120; site 19: TJE1133; site 20: TJE1148; site 25: TJE849; site 26: TJE853, TJE1025, TJE1026, TJE1057, TJE1106, TJE1319; site 27: TJE963; site 28: TJE864, TJE1053, TJE1101, TJE1330, TJE1331; site 30: TJE869; site 33: TJE877; site 34: TJE879; site 36: TJE884, TJE1252; site 39: TJE1228; site 43: TJE897 p.p.; site 44: TJE1240; site 45: TJE1367; site 49: TJE909; site 50: TJE915, TJE1159; site 52: TJE918, TJE1165; site 60: TJE947, TJE1201; site 63: TJE1205; site 65: TJE1209; site 67: TJE982, TJE1181; site 69: TJE962, TJE963, TJE1178; site 71: TJE969; site 72: TJE971, TJE1185; site 74: TJE975; site 77: TJE979; site 78: TJE986, TJE1030, TJE1108, TJE1109, TJE1320, TJE1338; site 80: TJE1003, TJE1235; site 81: TJE1006, TJE1239; site 82: TJE1011; site 83: TJE1117; site 84: TJE996; site 86: TJE1018; site 88: TJE1036; site 92: TJE1172; site 96: TJE1269; site 103: TJE1394, TJE1395; site 105: TJE1405; site 112: TJE1380; site 114: TJE1384; site 115: TJE1388; site 116: TJE1390; site 119: TJE1450.

Plants forming yellow-green to blue-green, velvety but amorphous mats; trichomes cylindrical (Fig. 5G–I), cells 2–9 μm in diameter, 2–10 μm long, L/D 0.5–3, cell contents granular but granules not lining septa; most terminal cells cylindrical (Fig. 5G) to slightly conical, 2–4.5 μm in diameter, 3–8 μm long, L/D 1.5–2.7, end-walls hemispherical or flattened, with no obvious thickening; sheaths absent (Fig. 5G) or present (Fig. 5H), thin, with no thick mucilage.

Habitat and phenology. Plants were found throughout the year; water temperature was 6–20°C. *S. friesii* was found in all but the most eutrophic of habitats. The populations are difficult to generalise about ecologically and may include a number of ecophenes (or even "species"). Their distribution may be limited by light intensity or temperature within an apparently broad range of nutrient tolerance. They usually grow in a habitat similar to that of *Oscillatoria retzii* C. Agardh sensu Drouet (1981), "at or just below the surface of relatively unpolluted water". Drouet (1981: 173) gave a broader range of habitats for *S. friesii* than for *O. retzii*.

Taxonomic remarks. There is much variation between populations in colour and size but most plants seem to have cylindrical or thimble-shaped terminal cells. The species is very broadly circumscribed here because no discrete subtaxa could be clearly delineated within it. It is possible that some populations should be included in *S. calcicola* (see Drouet 1968, 1981), which is distinguished from *S. friesii* in having more rotund terminal cells and generally thinner (less than 3.5 μm) trichomes. Trichomes resemble those of *Oscillatoria retzii* (C. Agardh) Gomont sensu Drouet in cell dimensions and shape but seem to lack thickened end-walls. In classical nomenclature and taxonomy, plants similar to those described above would be included in *Oscillatoria*, *Lyngbya* or *Phormidium*, the most similar species recorded by Desikachary (1959) perhaps being *O. retzii*.

A few populations (e.g. TJE979 and TJE1117) have brown, strongly-coloured septa, but this is not thought to be a useful specific character because the colour may be due to compounds accumulated from the water.

Rhodophyta

Batrachospermaceae Fries 1825: 341.

Thallus consisting of a central axis surrounded by whorls of fascicles; rhizoidal filaments often covering central axis, sometimes producing secondary fascicles. Reproduction by fusion of carpogonia and spermatia, subsequent formation of a carposporophyte and carpospores, and usually with production of a free-living uniseriate generation ("Chantransia").

Habitat and phenology. Members of the Batrachospermaceae are found in larger mountain creeks and in the Watts and upper Yarra Rivers. None were found in the Yarra River downstream of Woori Yallock Creek, but they are common in the Yarra and its tributaries farther upstream and in the Watts River basin. Populations mainly occur where the surrounding vegetation is natural forest or where there is minimal land disturbance or nutrient input. Habitats generally have low levels of phosphorus (less than 0.53 mg/L) and nitrogen (ammonia less than 0.26 mg/L, nitrate less than 0.61 mg/L) (see MMBW data in Campbell et al. 1982).

Most species are dominant in summer and autumn when water temperatures are above 9°C. *Batrachospermum keratophytum* is a notable exception in not producing new upright axes during summer and in growing at temperatures down to 6°C.

Reproduction by fusion of spermatium and relatively symmetrical carpogonium, resulting in globular or diffuse but limited gonimoblast; carpospores generally germinate into a creeping, uniseriate, diploid plant ("Chantransia"). Multiseriate gametophytes reproduced following somatic meiosis in an apical cell of the "Chantransia".

Remarks. In the Yarra River basin only *B. keratophytum* has an extensive and persistent "Chantransia" stage. The other species possibly have a transient or obscure filamentous stage which has evaded detection in this study.

Batrachospermum atrum (Hudson) Harvey 1841: 120. Entwisle & Kraft 1984: 226, figs 2A, B, 3A, B.

Fig. 6A–D

Distribution. Cosmopolitan; widespread throughout Victoria; Yarra River basin (Fig. 15J).

Specimens examined. Site 117: TJE1410, TJE1428.

Whorls rudimentary (Fig. 6A, B, D), apices acute (Fig. 6D); fascicles 1–5 cells long, branched 1–2 times. Carpogonia protruding from whorl (Fig. 6C). Gonimoblasts large, sessile on main axis, never more than one at each node. See Entwisle & Kraft (1984) for full description.

Key to genera of Batrachospermaceae

1.	Gonimoblast compact or loosely arranged, usually globular; gonimoblast filaments mostly determinate .... *Batrachospermum*
—	Gonimoblast diffuse; gonimoblast filaments all indeterminate 2
2.	Base of carpogonium not lobed .... *Nothocladus*
—	Base of carpogonium distinctly lobed .... *Sirodotia*

Batrachospermum Roth 1797: 36. Smith 1950: 619. Bold & Wynne 1985: 548, fig. 9.25a–e. Bourrelly 1985: 221.

Habitat and phenology. Plants were collected in spring; water temperature was 10°C. Israelson (1942) found *B. atrum* in Sweden in water with

Key to species of *Batrachospermum*.

1.	Whorls rudimentary, fascicles of 1–5 cells .... *B. atrum*
—	Whorls well-developed, fascicles of > 5 cells 2
2.	Outer cells of fascicles globular (or slightly obconical); whorls obovoid to obconical; gonimoblasts obscure, loosely arranged ... *B. keratophytum*
—	Outer cells of fascicles cylindrical or obovoid; whorls globular, barrel- or disc-shaped; gonimoblasts distinct, compact and globular 3
3.	Fascicle cells of similar diameter throughout, cylindrical; gonimoblast often in outer part of whorl .... *B. boryanum*
—	Fascicle cells varying in size and shape, mostly obovoid in distal part of fascicle; gonimoblast usually in inner part of whorl ... *B. gelatinosum*

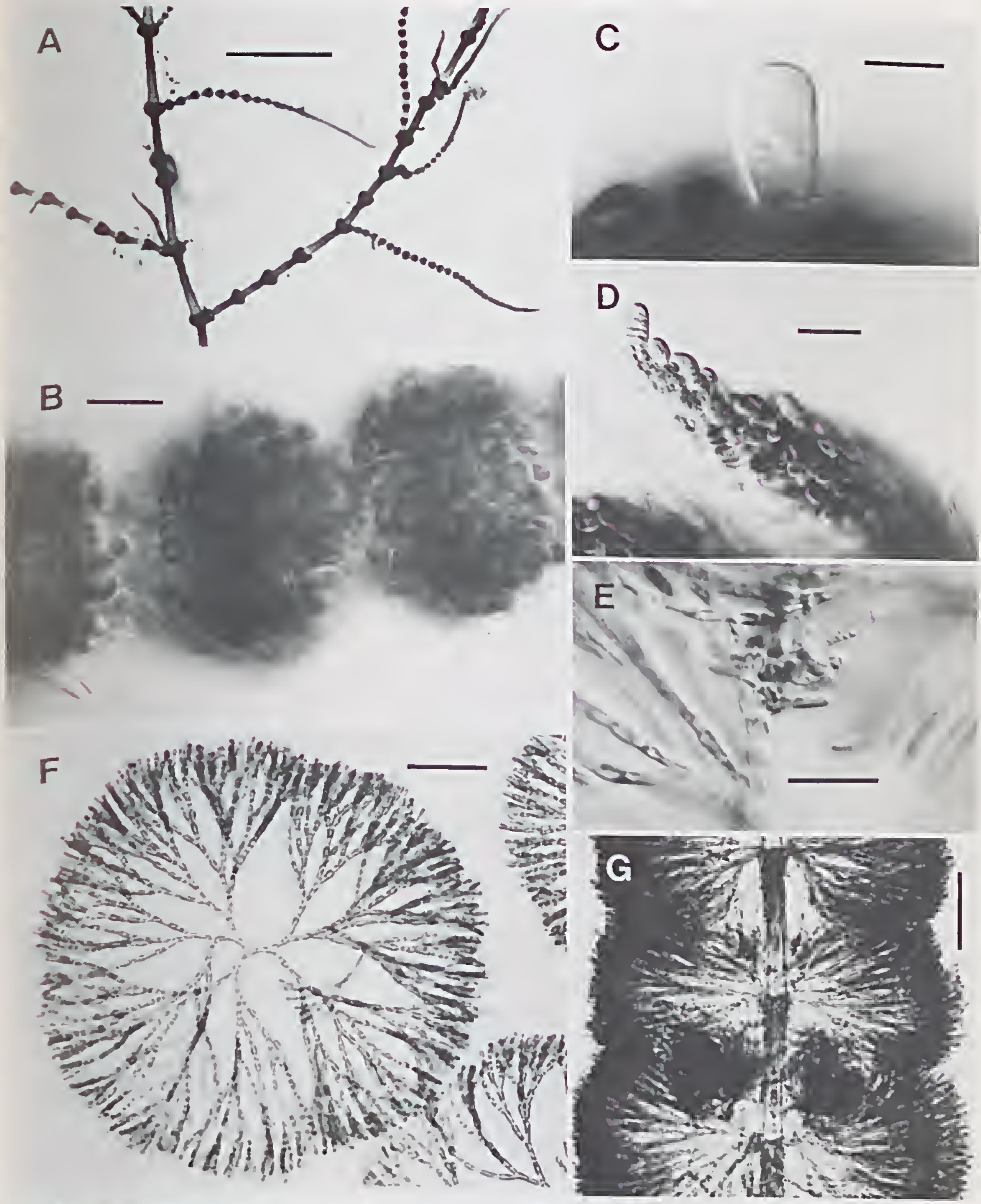


Fig. 6. A–D, *Batrachospermum atrum* (Hudson) Harvey. A, Habit of plant; note prominent axis in older branches with sparsely spaced whorls of fascicles. (TJE1428, scale 1 mm). B, Whorls of fascicles in young branch (TJE1410, scale 20 µm). C, Trichogyne protruding from whorl (TJE1410, scale 10 µm). D, Acute apex of plant with compact whorl fascicles (TJE1410, scale 20 µm). E–G, *Batrachospermum boryanum* Sirodot (TJE1139). E, Carpogonial branch arising form intercalary fascicle cell (scale 30 µm). F, Detached fascicles showing cell shape and branching pattern (scale 100 µm). G, Mature axis with globular gonimoblasts (scale 100 µm).

pH of 7.0–8.0 and with generally high levels of calcium. Streams in the Yarra River catchment are acidic and soft (unless polluted with organics and probably also with metals), and *B. atrum* has a restricted distribution. The only site at which it was found in the current study is in Running Creek, north of Melbourne. The EPA (pers. comm.) found that CaCO3 is high (730 mg/L in 1980 and 570 mg/L in 1983) in Running Creek near the junction with Arthurs Creek, while most other streams with low levels of nitrate, phosphate and metals have CaCO3 less than 100 mg/L (Victoria, EPA 1983). Although the conductivity measured at the collection site in Running Creek during the present study (167 µS/cm) was also higher than in most upper Yarra tributaries, the pH was 6.3, Ca was 8.0 mg/L and Mg was 1.2 mg/L, indicating that the water is relatively soft.

B. atrum has not been found in urban creeks during recent years but was recorded at site 12 in the lower reaches of Darebin Creek in 1979 (Entwisle & Kraft 1984). Its presence there may indicate a lower level of some toxic ion(s) in that year.

Batrachospermum boryanum Sirodot 1884: 246, pl. 29, figs 1–3, pl. 30, figs 1–5, pl. 31, figs 1–6. Sheath & Burkholder 1983: 324, figs 1–16. Entwisle & Kraft 1984: 254 (note added in proof).

Batrachospermum ectocarpum Sirodot 1884: 222, pl. 7, figs 1–5, pl. 8, figs 1–7. Entwisle & Kraft 1984: 228, fig. 6A–E.

Fig. 6E–G

Distribution. Cosmopolitan; seldom found in Victoria; Yarra River basin (Fig. 15J).

Specimen examined. Site 15: TJE1139.

Primary fascicle cells almost cylindrical (Fig. 6F), of similar diameter throughout; secondary fascicles absent (Fig. 6G). Carpogonial branches arising from periaxial and fascicle cells (Fig. 6E), carpogonia 20–30 µm long. Gonimoblast (Fig. 6G) often produced in outer part of whorl. See Entwisle & Kraft (1984: 230) for full description of species (as *B. ectocarpum*).

Habitat and phenology. Plants were found in autumn; water temperature was 11°C. *B. boryanum* was found in Sassafras Creek not far from the site of the only other recent record of the species in Australia, in Sherbrooke Creek, Belgrave (Entwisle & Kraft 1984). Both sites were heavily shaded, and *B. boryanum* also occurs in habitats with low light in the United States (Blum 1957). The Sassafras Creek site is also situated in part of the Yarra River catchment with high suspended solids (Victoria EPA 1982). In January 1988 the site was acidic (pH 5.7) but had relatively high electrolytes (conductivity 130 µS/cm, Ca 16.8 mg/L, Mg 1.2 mg/L) in comparison with upper Yarra tributaries.

Taxonomic remarks. No spermatangia were found on the plants from the Yarra River basin, so it is possible that the population is dioecious rather than monoecious like the populations described by Etwisle & Kraft (1984).

Batrachospermum gelatinosum (Linnaeus) de Candolle 1802: 440.

Batrachospermum moniliforme Roth 1800: 480. Sheath & Hymes 1980: 1308, figs 37–44. Sheath 1984: figs 41–45.

Batrachospermum helminthoideum (Sirodot) Mori 1975: 474. Entwisle & Kraft 1984: 230, figs 7A–F, 8A–F.

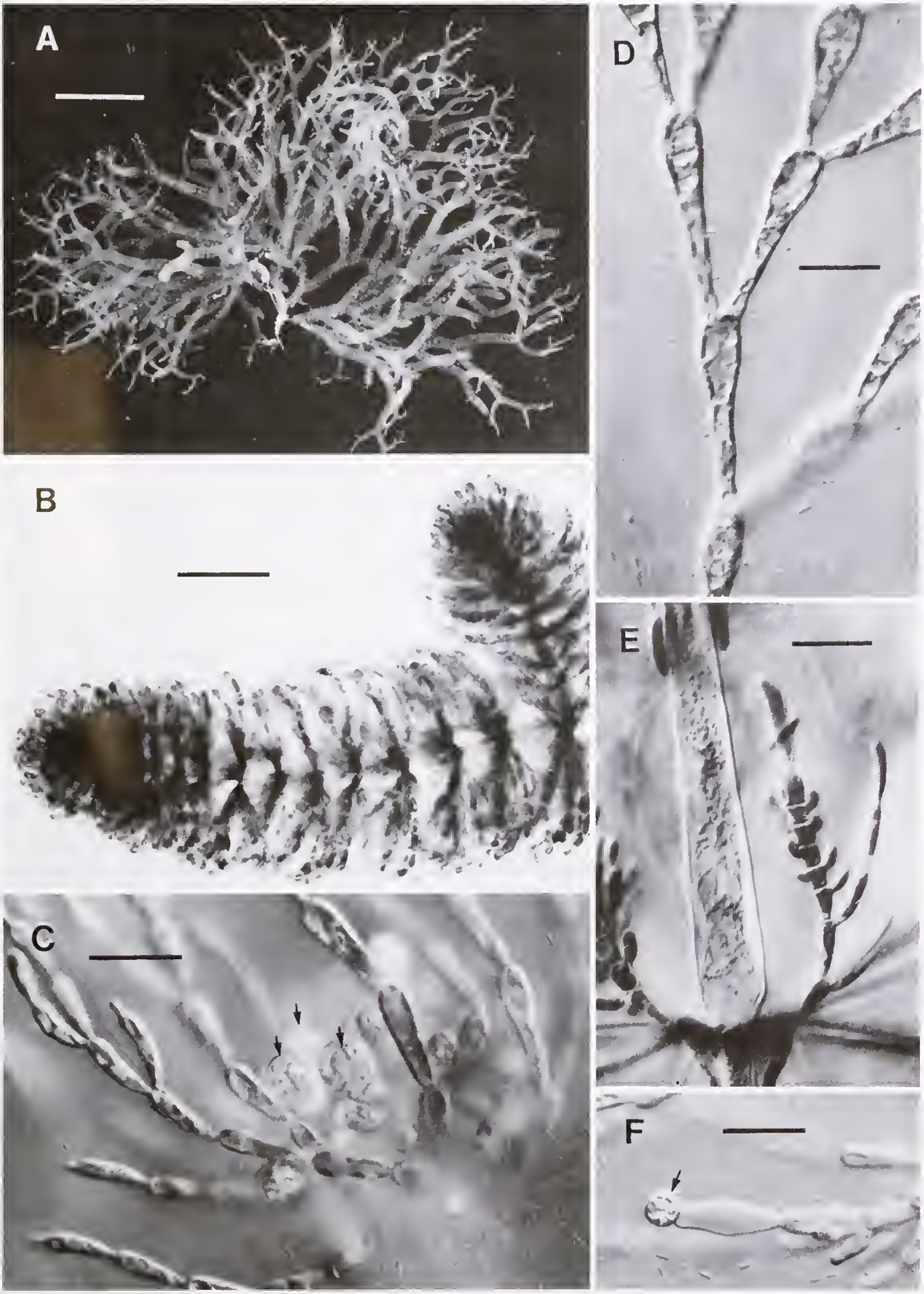
Figs 7, 8A–N

Distribution. Cosmopolitan; widespread throughout Victoria; Yarra River basin (Fig. 16A).

Specimens examined. Site 14: TJE1136; site 18: TJE1127; site 19: TJE1129, TJE1130; site 20: TJE1147; site 21: TJE1144; site 24: TJE1153; site 25: TJE1151; site 26: TJE1103, TJE1215, TJE1282, TJE1301; site 28: TJE1296; site 30: TJE1232; site 39: TJE1227; site 40: TJE890, TJE1230; site 44: TJE898, TJE1243; site 51: TJE916; site 52: TJE1167; site 53: TJE921, TJE1170; site 64: TJE1208; site 72: TJE970, TJE1184; site 74: TJE973; site 76: TJE980; site 78: TJE1063, TJE1112, TJE1113, TJE1220, TJE1287, TJE1304; site 83: TJE1066, TJE1223, TJE1288, TJE1308.

Plants tufted, mucilaginous, 10–60 mm high, richly branched (Fig. 7A), main axis percurrent, lateral branches of same thickness at insertion, often with U-shaped axils; colour grey, brown, violet-brown to olive; compact resistant portion of lower thallus at times acting to maintain

Fig. 7. Batrachospermum gelatinosum (Linnaeus) de Candolle. A, Habit of plant, partly figured by Entwisle & Kraft 1984, fig. 8D (23973, scale 4 mm). B, Apex of plant (TJE1147, scale 100 µm). C, Compact gonimoblast with carposporangia (arrows) (TJE1129, scale 20 µm). D, Whorl fascicle showing cell shape and branching pattern (TJE1144, scale 20 µm). E, Carpogonial branch with few bracteae (TJE1113, scale 20 µm). F, Carpogonium with spermatium attached (arrow) (TJE1129, scale 20 µm).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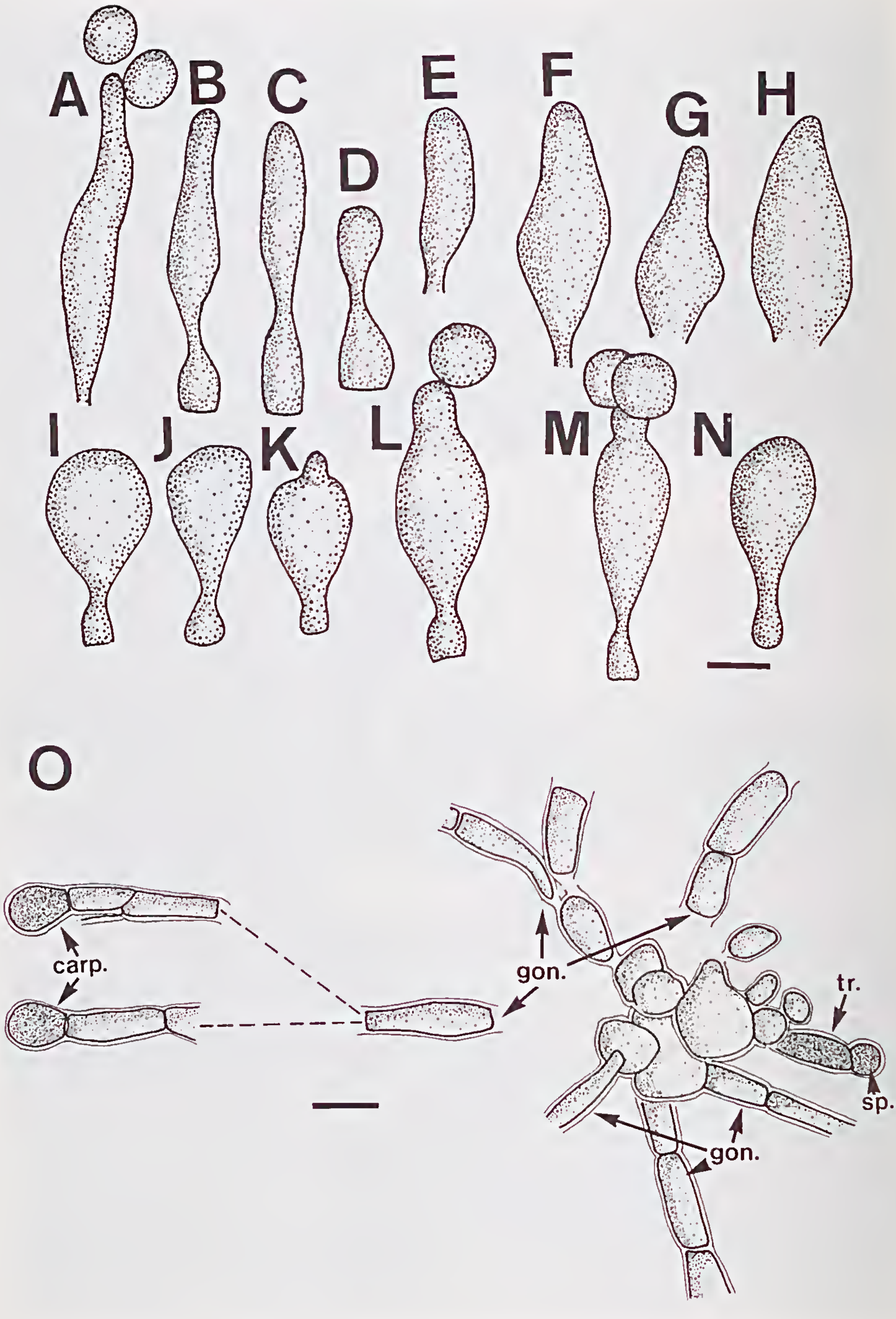
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plants between growing seasons; apices usually blunt (Fig. 7B).

Central axis 20–90 µm in diameter, with abundant rhizoidal filaments and occasional secondary fascicles (more in older thalli); internodes 250–610 µm long; whorls globular to barrel-shaped, separate to confluent, 400–1000 µm in diameter; primary fascicles 2–4 per periaxial cell, each fascicle branching di- or trichotomously 5–8 times, composed of 8–15 cell layers; distal ends of fascicles at times slightly curved; fascicle cells mostly fusiform to obovoid (Fig. 7D); periaxial cells cylindrical to pyriform, 4–10 µm in diameter, 9–25 µm long; proximal cells narrowly elongate with swollen ends, 2–8 µm in diameter, (12–)20–55(–62) µm long, L/D 3–15; distal cells obovoid, 2–5 µm in diameter, 4–12 µm long. Hairs present or absent, of variable length, up to 40 µm long.

Plants monoecious or dioecious; spermatangia globular to subglobular, 4–7 µm in diameter, 6–9 µm long, produced terminally on fascicles. Carpogonial branches of 5–10 cells arising from periaxial cells (Fig. 7E), and proximal cells of fascicles, in place of bracteae, also rarely from rhizoidal filaments; carpogonia 2–7 µm in diameter at base, 20–65 µm long, produced in inner part of whorl; trichogyne fusiform to cylindrical (Figs 7E, F, 8A–E), urceolate (Fig. 8E–H) or clavate to inflated obpyriform (Fig. 8I–N); bracteae short to long, of varying density. Gonimoblast globular, 70–150(–180) µm in diameter, usually produced in inner part of whorls, 2–5 at each node; cells of post-fertilisation carpogonial branch generally barrel-shaped; carposporangia ellipsoid, obovoid or pyriform (Fig. 7C), 7–15 µm in diameter, 12–22 µm long.

Habitat and phenology. Plants were found in spring, autumn and early winter; water temperature was 10–18°C. *B. gelatinosum* was found throughout the Watts River and the upper part of the Yarra catchment. It seems to tolerate some eutrophication (being common around Warburton) and grows mostly in shaded parts of larger, well-lit rivers, although it can also grow in smaller shaded streams. Fjerdingstad (1965) found it to be tolerant of pollution. In larger rivers it usually grows with *Nothocladus nodosus*, the two species often forming extensive growths on large rocks in autumn.

Taxonomic remarks. Observations on additional Australian populations of *Batrachospermum* having small gonimoblasts scattered in the inner part of whorls has led to a broadening of the species concept for these plants. There is considerable variation in trichogyne shape (Fig. 8A–N), as reported in other groups of species (e.g. Sheath & Burkholder 1983, Entwisle & Kraft 1984), and no other characters were found which could be used to distinguish taxa within this group. Two dioecious populations, one also characterised by inflated trichogynes (TJE970, TJE1184; Fig. 8I–K), the other by a gelatinous, dense thallus (TJE890, TJE1230), were found in the Yarra River basin. The use of monoeciousness or dioeciousness as taxonomic characters has been abandoned in most Rhodophyta, and both unisexual and bisexual plants have been reported in a number of *Batrachospermum* species (Israelson 1942). In no other features are there any clear disjunctions, and so all of the plants have been included in *B. gelatinosum.*

Batrachospermum gelatiosum is the oldest available name for plants similar to those described, and is therefore more suitable than the more narrowly defined *B. helminthoideum* used by Entwisle & Kraft (1984). *B. moniliforme*, a superfluous name, has been commonly used instead of the homotypic *B. gelatinosum* (Necchi 1988).

Batrachospermum keratophytum Bory de St-Vincent 1808: 328, pl. 31, fig. 2. Entwisle & Kraft 1984: 234, fig. 9A–E.

Figs 8O, 9

Distribution. Widespread throughout Victoria; Yarra River basin (Fig. 16D).

Specimens examined. Site 14: TJE829; site 26: TJE988; site 34: TJE1249; site 40: TJE888; site 45: TJE899, TJE900, TJE1244, TJE1245, TJE1370, TJE1430, TJE1476; site 53: TJE920, TJE1169; site 60: TJE945; site 62: TJE951; site 63: TJE954, TJE1203; site 64: TJE956, TJE957; site 68: TJE961, TJE1176, TJE1177; site 75: TJE976; site 79: TJE1303; site 81: TJE1005; site 83: TJE1427; site 104: TJE1398, TJE1479; site 105: TJE1404; site 106: TJE1399, TJE1401, TJE1480; site 116: TJE1391, TJE1392. MEL 685659, MEL 685658, Fernshaw, 11.xi.1900, Bastow.

Fig. 8. A–N. *Batrachospermum gelatinosum* (Linnaeus) de Candolle. Variation in trichogyne size from fusiform (A–D, TJE1147) to urceolate (E–H, TJE1127) to clavate or inflated obpyriform (I–N, TJE970) (scale 10 µm). O, *Batrachospermum keratophytum* Bory de St-Vincent; gon. = gonimoblast, tr. = trichogyne, sp. = spermatium, carp. = carposporangia. Note that gonimoblast development was seldom seen (TJE1479, scale 10 µm).

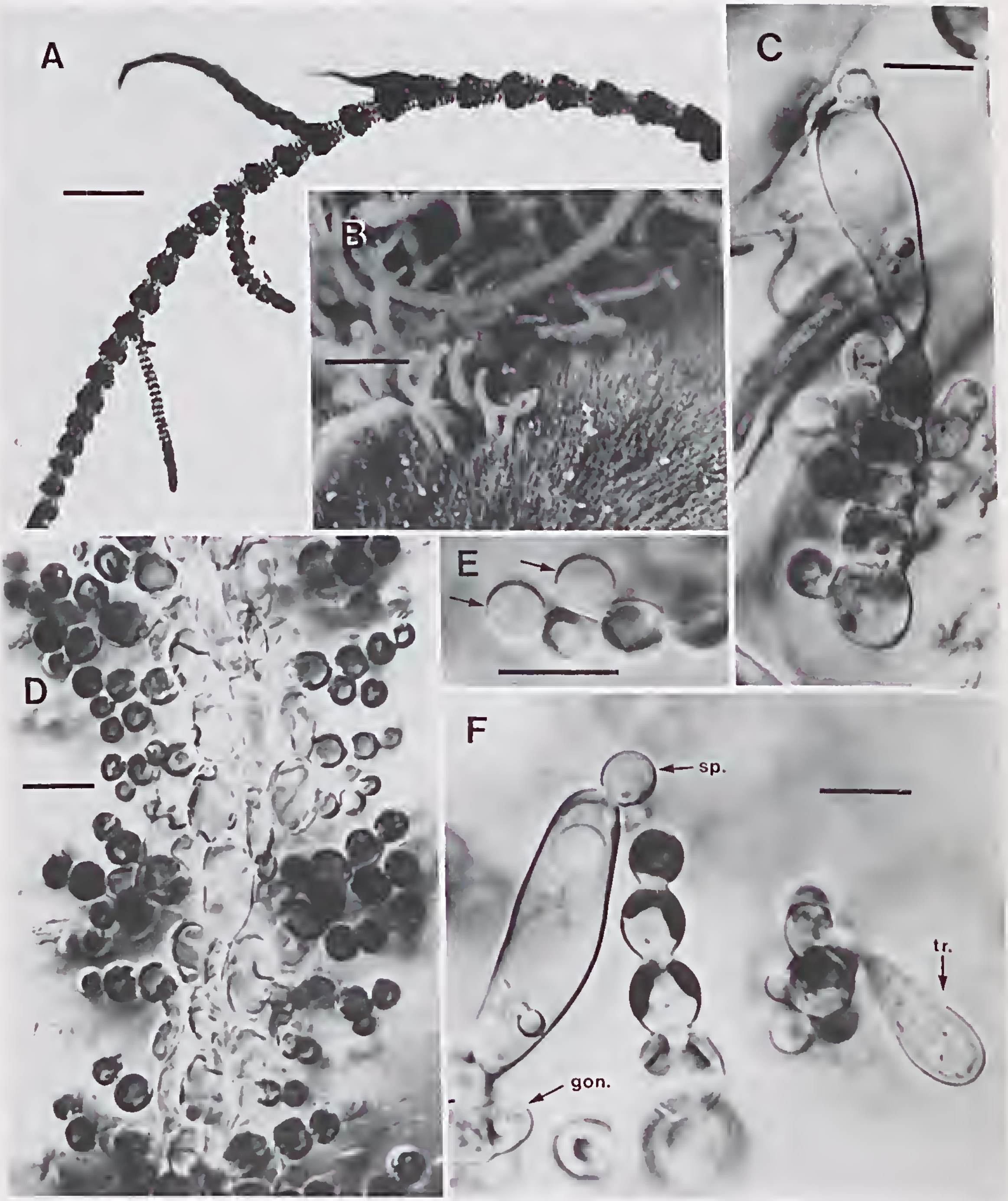


Fig. 9. Batrachospermum keratophytum Bory de St-Vincent. A, Habit of plant showing truncate-conical whorls and branching (TJE1430, scale 1 mm). B, Gametophytic plant (with whorls) arising from filamentous stage (TJE1399, scale 2 mm). C, Carpogonial branch detached from plant (TJE1401, scale 10 μm). D, Young branch showing cell shape and arrangement (TJE1370, scale 20 μm). E, Spermatia terminating fascicles in "male" plant (TJE1391, scale 10 μm). F, Two carpogonia in cortex of plant and fascicle showing cell shape; tr. = trichogyne, gon. = probable gonimoblast filament, sp. = spermatium (TJE1401, scale 10 μm).

Multiseriate plant rigid, mucilaginous, 20–50 mm high and irregularly branched (Fig. 9A; usually 45–90°), olive-green to red-brown in older plants; whorls 200–450 µm wide, ovoid, pyriform (Fig. 9A, D), occasionally barrel-shaped or cylindrical in older plants, 200–450 µm long; always confluent; central axis may be denuded in abraded plants, except for swollen rhizoidal filaments.

Central axis 20–80 µm in diameter, with abundant rhizoidal filaments and secondary fascicles (Fig. 9D); internodes 200–500 µm long; fascicles 2(–3) produced terminally from each periaxial cell but additional fascicles produced laterally; periaxial cells cylindrical, 8–12 µm in diameter, 25–55 µm long; proximal cells of fascicles 4–10 µm in diameter, 15–50 µm long, L/D 2–7; intermediate cells cylindrical, ellipsoid to obovoid-globular (Fig. 9D); distal cells short conical-globular (Fig. 9F), 3–10 µm in diameter, 3–12 µm long, L/D 1–1.5.

Plants dioecious; spermatia globose (Fig. 9E), 5–6 µm in diameter, produced terminally and profusely on most fascicles. Carpogonial branches 4–6 cells long, relatively straight (Fig. 9C) to slightly curved, arising from periaxial cells and rhizoidal filaments; carpogonia 3–4 µm in diameter at base, 20–25 µm long, usually straight; trichogyne clavate to elongate-ellipsoid (Fig. 9C, F), usually reaching surface of plant; bracteae common but short. Gonimoblast consisting of a few swollen cells borne directly on carpogonium and determinate and indeterminate filaments spreading through cortex (Fig. 8O); carposporangia difficult to detect, terminal or lateral, obovoid, 5–8 µm in diameter, 8–11 µm long; no released carpospores seen.

Simple filamentous stage ("Chantransia") red to red-brown, branched, forming tangled to tufty mat on rocks, to 3 mm high; cells cylindrical, 8–12 µm in diameter, 12–32 µm long, L/D 1–5; gametophytic plants produced directly (Fig. 9B) by conversion of simple filament to central axes.

Habitat and phenology. Upright plants are common in autumn and spring, but denuded orange-brown axes sometimes persist through summer; water temperature was 6–13°C. *B. keratophytum* grows mainly in well-shaded, cooler streams but can also grow on stable substratum in larger rivers (e.g. Little Yarra River, Yarra Junction; this population was found after the completion of the current study). Measured pH was 6.3–6.4 and conductivity 98–103 µmS/cm at sites 45 and 104 (in January and March 1988).

Fertilisation of carpogonia seems to occur infrequently and only late in the season. In many localities the plants do not seem to reach sexual maturity. The "Chantransia" stage is always present, however, and seems to provide the main method of surviving unfavourable conditions and producing new gametophytes. All other batrachospermaceous plants in the Yarra River basin produce abundant carpospores throughout their growing period.

Taxonomic remarks. The discovery of a loosely arranged gonimoblast allies this species with the genus *Nothocladus*, which it also resembles in the frequent internodal carpogonial branches, the symmetrical carpogonial base with a long fusiform to clavate trichogyne, and the rigid thallus without a compact outer cortical layer (cf. *Tuomeya*). It differs from species of *Nothocladus*, however, in possessing the following features (see also Table 4):

(a) determinate gonimoblast filaments as well as limited growth of apparently indeterminate filaments;

(b) a prolific "Chantransia" stage in its life history (thus exhibiting a "*Lemanea*" type of life history);

(c) dioecious gametophytes with profuse production of spermatia on male plants;

(d) distal and most secondary cells of fascicles that are globular (cf. Figs 10B, C, D, 11B);

(e) ovoid whorls with no regular outer surface;

(f) relatively straight carpogonia.

The first feature is sufficient to retain this taxon in *Batrachospermum*, and the remaining features distinguish it from other batrachospermaceous plants in the Yarra River basin. Entwisle & Kraft (1984: 252) noted that the generic affinities of this taxon were uncertain since no gonimoblasts were seen, but it was tentatively referred to *B. keratophytum* which it seemed most to resemble vegetatively. The gonimoblasts observed in the current study, although not compact, are relatively limited in growth and include short determinate filaments. This type of gonimoblast structure has been found in a number of species of *Batrachospermum* (Necchi 1988), including Brazilian plants referred to *B. keratophytum*. The assignment of these plants to *B. keratophytum* is therefore retained until the type material can be examined, and the delineation of genera in this family is re-evaluated.

Nothocladus Skuja 1934: 186. Bourrelly 1985: 230.

Vegetative morphology similar to *Batrachospermum* but plants usually more rigid and with denser cortex; reproduction similar also, but gonimoblasts diffuse rather than compact.

Remarks. No simple filaments ("Chantransia" stages) were found with any *Nothocladus* specimens, and even very young plants had no uniseriate filaments attached to their bases (rocks were carefully examined in a number of cases). The "Chantransia" stage is therefore presumed to be transient and inconspicuous or entirely absent. Elucidation of the life cycle of *Nothocladus* in culture is needed.

Habitat and phenology. Plants were found in late spring, summer and autumn; water temperature was 9–16°C. *N. lindaueri* grows in both large and medium-sized rivers but not in heavily shaded creeks.

Remarks. Nothocladus lindaueri produces many carpogonia in young parts of the thallus but, as reported by Entwisle & Kraft (1984), none of these have spermatia attached. Spreading through the thallus, however, are specialised fascicles producing spermatia (see Entwisle & Kraft 1984, fig. 15A).

Some additional features help to separate the two *Nothocladus* species. *N. lindaueri* is difficult to compress (under a coverslip), the profusely branched, short-celled fascicles (Fig. 10B, C) creating a compact outer cortex. In contrast to *N. nodosus*, the thallus is usually cylindrical rather than moniliform, and brown-black to dark-blue rather than olive-green.

Key to Species of *Nothocladus*

1.	Apical cell of branches protruding; thallus difficult to compress, main axis not visible	*N. lindaueri*
—	Apical cell embedded in whorl; thallus easy to compress, main axis usually visible	*N. nodosus*

Nothocladus lindaueri Skuja 1944: 11, pls 2, 3. Entwisle & Kraft 1984: 246, figs 14A–F, 15A, B, D–F.

Fig. 10

Type material. Dr O. Necchi Jr has chosen a lectotype for this species from the material held in UPS. Numerous isotypes are distributed as part of V.W. Lindauer's herbarium.

Distribution. North Island of New Zealand; relatively common in Victoria; Yarra River basin (Fig. 16B).

Specimens examined. Site 18: TJE1128; site 21: TJE1143; site 26: TJE989; site 44: TJE1242; site 51: TJE1162; site 52: TJE1166; site 66: TJE1210; site 69: TJE1179; site 74: TJE1186; site 75: TJE1188; site 76: TJE981; site 79: TJE1216; site 80: TJE1002; site 81: TJE1009, TJE1237; site 83: TJE994; site 88: TJE1037.

Alterations and additions to the description of the species by Entwisle & Kraft (1984: 246) are given in the remarks below and in Table 4. The protruding apical cell (Fig. 10A), fascicle cell shape (Fig. 10B, C, D), and compactness of the cortex (Fig. 10F, G) separate this species from *N. nodosus.* The position of the carposporangia in the outer cortex can be seen in Fig. 10E, G.

Nothocladus nodosus Skuja 1934: 186, pl. 2. Entwisle & Kraft 1984: 242, figs 13A–D, 15C, G–J.

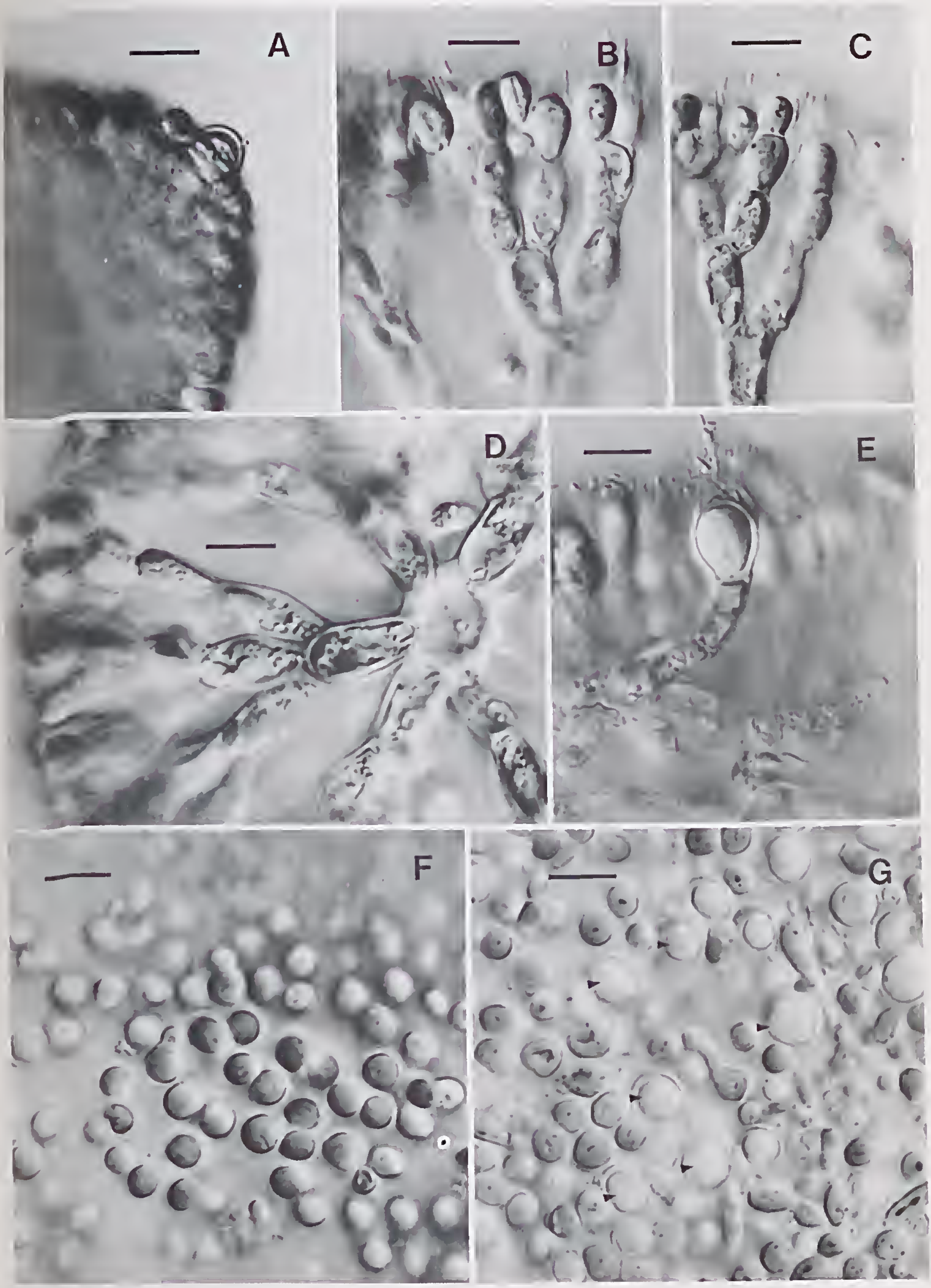
Nothocladus tasmanicus Skuja 1934: 187, pl. 3.

Fig. 11

Type material. There are no extant specimens of *N. nodosus* in B (S. Wendker, Curator of Algae, pers. comm.), the herbarium in which a specimen of this species was first noticed by Skuja (1934), and Dr O. Necchi Jr has chosen a specimen in UPS as the lectotype. Dr Necchi has also chosen a specimen held in UPS as the lectotype of *N. tasmanicus.* The synonymy of these two species, suggested by Entwisle & Kraft (1984), has been confirmed by an examination of the type materials.

Distribution. Widespread throughout Victoria; Yarra River basin (Fig. 16C).

Fig. 10. Nothocladus lindaueri Skuja (TJE1188, scale 10 µm). A, Apex of branch showing protruding apical cell (see Entwisle & Kraft 1984, fig. 15B, E, F for illustrations of mature thallus). B, Distal end of fascicle showing cell shape and arrangement. C, Distal end of fascicle showing cell shape. D, Fascicle whorl detached from thallus. E, Carposporangia near surface of plant; note gonimoblast filament (arrow) spreading through cortex. F, Surface view of young branch without carposporangia. G, Surface view of older branch with carposporangia (e.g. arrowheads).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Species	"Chantransia" Stage	Distribution of gametangia	Diameter of mature whorls (µm)	Main axis	Thallus apical cell	Fascicle distal cell L/D	Fascicle proximal cell length (µm)	Most carpogonia
N. lindaueri Skuja	unknown	monoecious	(100–)200–500(–600)	obscure	protruding	1–2	12–15(–20)	curved
N. nodosus Skuja	unknown	monoecious	(280–)400–800(–1000)	visible	in cortex	> 2	(25–)32–40(–48)	curved
B. keratophytum Bory	common	dioecious	200–450	visible	protruding	1	15–30	straight

Table 4. Characteristic features of *Nothocladus lindaueri*, *N. nodosus* and *Batrachospermum keratophytum* species found in Australia.

Specimens examined. Site 20: TJE1146; site 24: TJE1154; site 25: TJE1150; site 26: TJE1061, TJE1104, TJE1284, TJE1302; site 46: TJE903, TJE1246; site 76: TJE978; site 78: TJE1064, TJE1111, TJE1219, TJE1286, TJE1305, TJE1445; site 79: TJE1217, TJE1477; site 83: TJE994, TJE1115, TJE1292, TJE1311; site 88: TJE1037, TJE1225. MEL 68504, *N.nodosus*, isotype, H. Watts.

Alterations and additions to the description of the species by Entwisle & Kraft (1984: 244) are given in the remarks below and in Table 4. The relatively loose outer cortex (Fig. 11A), fascicle cell shape (Fig. 11B) and an apical cell which does not protrude beyond the fascicles distinguish this species from *N. lindaueri*. The reproductive features of *N. nodosus* (Fig 11C–F) have been little illustrated in the past.

Habitat and phenology. Plants were found in late spring, summer, autumn and early winter; water temperature was 9–18°C. *N. nodosus* was always found in well-lit larger rivers, often in shaded areas and commonly associated with *Batrachospermum gelatinosum*. In the 1880s *N. nodosus* was found in the Yarra River at Collingwood but is now known only from upstream of Yarra Junction (Fig. 16C).

Remarks. The antheridia in *Nothocladus nodosus* are produced terminally on specialised fascicles (Fig. 11D). Note that Entwisle & Kraft (1984) incorrectly stated that the spermatia terminate a diffusely growing filament; their fig. 15A in fact shows spermatia on an endophytic *Audouinella*. The spermatia of *N. nodosus* are larger than reported by Entwisle & Kraft (1984), usually 4–10 µm in diameter, and are often obovoid rather than globose before release.

Nothocladus is generally characterised by being cartilaginous. *N. nodosus*, however, is less rigid than *N. lindaueri* and the fascicles are easily spread out in microscope slide preparation. Although most species of *Batrachospermum* are flaccid, *B. keratophytum* can be quite cartilaginous. The differences between *N. nodosus*, *N. lindaueri* and *B. keratophytum* are summarised in Table 4.

Sirodotia Kylin 1912: 38. Smith 1950: 619. Bourrelly 1985: 228.

Vegetative morphology similar to *Batrachospermum* but whorls often more separate and tapered. Reproduction is also similar, but carpogonium has a distinct lobe and gonimoblast is diffuse.

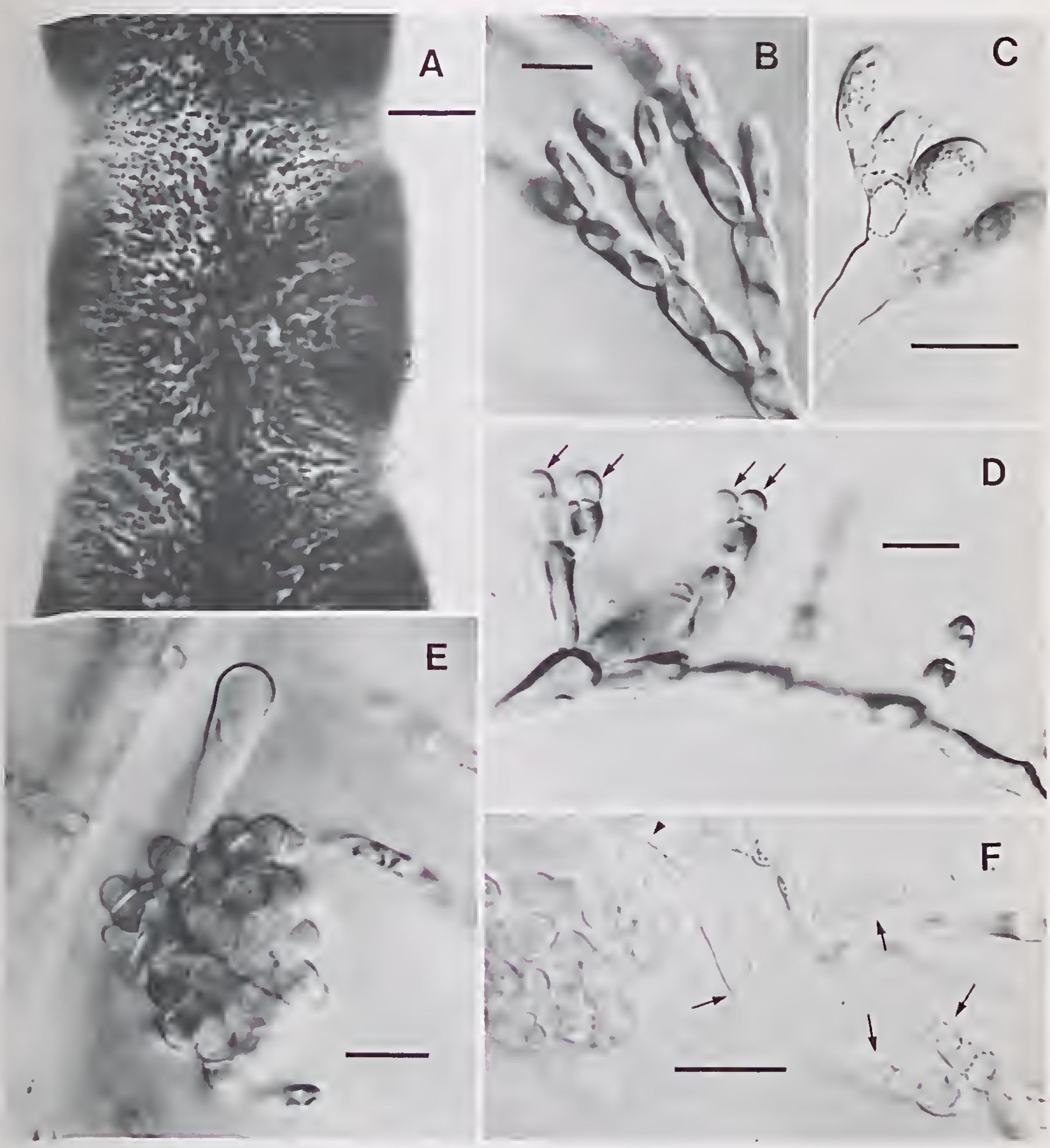


Fig. 11. Nothocladus nodosus Skuja. A, Mature branch (not compressed in slide preparation) (TJE1146, scale 100 µm); note that main axis is just visible, and that fascicles are dense but not forming compact outer cortex as in *N. lindaueri;* thallus is often more open (see Entwisle & Kraft 1984, fig. 13B–D). B, Fascicle showing cell shape and arrangement (TJE1037, scale 10 µm). C, Carposporangia terminating gonimoblast filament (TJE1462, scale 20 µm). D, Spermatia terminating fascicle (TJE1037, scale 10 µm). E, Trichogyne arising from carpogonial branch with dense bracteae (TJE1037, scale 20 µm). F, Gonimoblast filaments (arrows) spreading through thallus; note carpogonial branch with obscuring bracteae to left of photograph, and gonimoblast filament (arrowhead) arising from that mass (TJE1462, scale 20 µm).

Sirodotia suecica Kylin 1912: 38, fig. 3. Sheath & Hymes 1980: 1306, figs 18–25. Entwisle & Kraft 1984: 238, figs 11A–F, 12A–E.

Distribution. Cosmopolitan; few known localities in Victoria; Yarra River basin (Fig. 16E).

Specimens examined. Site 19: TJE1134; site 21: TJE834; site 50: TJE914, TJE1160; site 80: TJE1004.

Plants mucilaginous, richly branched, green to blue-green, 10–80 mm high; main axis percurrent; apices blunt or tapered.

Central axis 25–80 µm wide, with abundant rhizoidal filaments and secondary fascicles; internodes 150–800 µm long; whorls small, ellipsoid, obovoid or obpyriform, 250–350 µm in diameter, confluent or separated, usually tapering; primary fascicles 3–5 per periaxial cell, branched dichotomously 3–6 times, 4–10 cells long; cells ellipsoid-cylindrical to obovoid; proximal cells 2–7 µm in diameter, 10–30 µm long; distal cells 3–6 µm in diameter, 7–13 µm long. Hairs rare, up to 40 µm long.

Plants monoecious and dioecious; spermatia globular, 4–5.5 µm in diameter, terminating fascicles. Carpogonial branches of 3–4(–5) cells arising from periaxial cells, proximal cells of fascicle, and sometimes rhizoidal filaments; carpogonia 4–8 µm in diameter at base, with distinctive asymmetric swelling, and 19–42 µm long; trichogyne ellipsoid, pyriform or cylindrical. Gonimoblast initial arising from side opposite to the swelling on carpogonial base, and producing indeterminate filaments; carposporangia ellipsoid, ovoid or pyriform, (4–)6–8 µm in diameter, 8–10 µm long.

Habitat and phenology. Plants were found in spring and autumn; water temperature was 11–13°C. All sites are in southern tributaries of the Yarra River, in streams that mostly flow through mudstone and sandstone. Non-filterable residues (suspended solids) are high in these streams (Victoria, EPA 1983). Site 50 was acidic (pH 6.0) but reasonably conductive (133 µmS/cm).

Taxonomic remarks. Since there is no clear or consistent disjuction between the two "forms" of *S. suecica* reported by Entwisle & Kraft (1984) they have been combined in the above description. The relationship between *S. suecica* and other *Sirodotia* species is discussed by Entwisle & Kraft (1984: 242).

A number of plants collected from the Yarra River basin seem to be unisexual, so the description has been expanded to include dioecious plants in what is usually reported as a monoecious taxon (Israelson 1942).

Compsopogonaceae Schmitz 1896: 318.

Remarks. Only one macroalgal genus of this family has been found in the Yarra River basin.

Compsopogon Montagne 1846: 152. Smith 1950: 610. Bourrelly 1985: 208.

Young filaments uniseriate, becoming corticated and having compact arrangement of periaxial cells; no obvious cytoplasmic connections between cells. Reproduction by monospores that are cleaved from outer cortical cells.

Compsopogon coeruleus (Balbis) Montagne 1846: 154. Entwisle & Kraft 1984: 220, fig. 4A–G.

Distribution. Widespread in temperate and subtropical areas; limited to a few river basins in Victoria; Yarra River basin (Fig. 16F).

Remarks Although periodically common in Darebin and Merri Creeks in 1980–81 (Entwisle & Kraft 1984), this species was not found during the current study.

Porphyridiaceae Kylin ex Skuja 1939: 31.

Remarks. Only one genus forming macroscopic clumps has been found in the Yarra River basin.

Chroodactylon Hansgirg 1885: 14.

Ellipsoid cells loosely arranged in uniseriate branched chains, with no cytoplasmic connections; chloroplast stellate and axial. Monospores formed from entire vegetative cells.

Chroodactylon ornatum (C.Agardh) Basson 1979: 67, pl. 9, fig. 52. Entwisle & Kraft 1984: 218, fig. 3C, D.

Distribution. Cosmopolitan; few collections in Victoria; Yarra River basin (Fig. 16F).

Remarks. This small alga is barely in the "macroalgal" category. No specimens were found in the present study but they may have been overlooked, as the species was recorded by Entwisle & Kraft (1984).

Rhodochortaceae Nasr 1947: 92.

Remarks. Audouinella is the only genus of this family forming macroscopic clumps in the Yarra

River basin. An endophytic *Audouinella* (= *Balbiania* Sirodot) was found growing in *Sirodotia suecica* and all three species of *Nothocladus*, but it is not described in the present work which includes only macroscopic benthic algae.

Audouinella Bory de St-Vincent 1823: 340. Smith 1950: 618. Bold & Wynne 1985: 556. Bourrelly 1985: 216.

Uniseriate branched filaments with parietal, ribbon-like or plate-like chloroplasts; pit connections between cells; reproduction mainly by terminal monospores in freshwater, but carpogonia, spermatia and tetrasporangia frequently reported.

Audouinella hermannii (Roth) Duby 1830: 972. Entwisle & Kraft 1984: 223 (with incorrect author citation).

Audouinella violacea (Kützing) Hamel 1925: 57. Sheath & Hymes 1980: 1302, figs 14–17.

Chantransia hermannii (Roth) Desvaux 1809: 310. Israelson 1942: 15.

Distribution. Cosmopolitan; seldom collected in Victoria; Yarra River basin (Fig. 151).

Specimens examined. Site 16: TJE1093, TJE1118; site 58: TJE1070; site 89: TJE1174, TJE1175; site 100: TJE1274, TJE1276.

Thallus erect, forming tufts on stones, concrete or willow roots; consisting of cylindrical cells in uniseriate, branched filaments. Reproduction usually by monospores. See Entwisle & Kraft (1984: 223) for full description.

Habitat and phenology. Plants were found in autumn; water temperature was 16–19°C. *A. hermannii* is usually found in streams with some nutrient input but not in the heavily polluted urban creeks. Biggs & Price (1987) found *A. hermannii* in regulated streams subject to some disturbance, with exotic willows providing some substrata.

Taxonomic remarks. Audouinella hermannii, as conceived in the broad sense now adopted by most contemporary workers, includes most tufted aggregates of sparingly branched uniseriate filaments with pit-connected cells and frequent monosporic reproduction. Some collections (TJE889, TJE1176, TJE1249, TJE1226, TJE1229) were judged to be part of a batrachospermaceous life history (Fig. 151), the filaments of these plants being little aggregated and without monospores, and growing with typical batrachospermaceous plants nearby or attached. Plants in the Plenty River, Toorourrong Reservoir catchment (TJE1456) were aggregated but had no monospores or associated batrachospemaceous plants, and could not be adequately classified.

GENERAL REMARKS ON THE YARRA RIVER BASIN FLORA

Most genera of macroalgae found in the Yarra River basin are distributed widely around the world. The exceptions are *Palmellopsis* (although some collections of this genus may have been referred to *Tetraspora*); *Parallela* from North and South America and New Zealand; *Tetrasporopsis* from Europe; and *Nothocladus* from Madagascar and New Zealand. Some species seem to be restricted in distribution, but there are often doubts about species delineations which confuse biogeographical attributions.

Conversely, some genera which are reported to be very common in seemingly comparable overseas habitats were not found in the Yarra River basin. These genera include *Tuomeya*, *Lemanea* (both similar in habit and habitat to *Nothocladus*), *Thorea* and *Bangia* of the Rhodophyta, *Stigonema* (similar in habit and habitat to *Scytonema hofmannii*) of the Cyanophyta, and *Hydrurus* of the Chrysophyta.

No doubt further studies in the area will discover new records, but the current flora should provide a basis for future assessments on the macroalgae of the Yarra River basin. The taxonomic groups most in need of intensive study to clarify species concepts are the Ulotrichaceae and the Cyanophyta, while reproductive material of various "taxa" in the Zygnemataceae and Oedogoniaceae is needed for meaningful identification of species in these families.

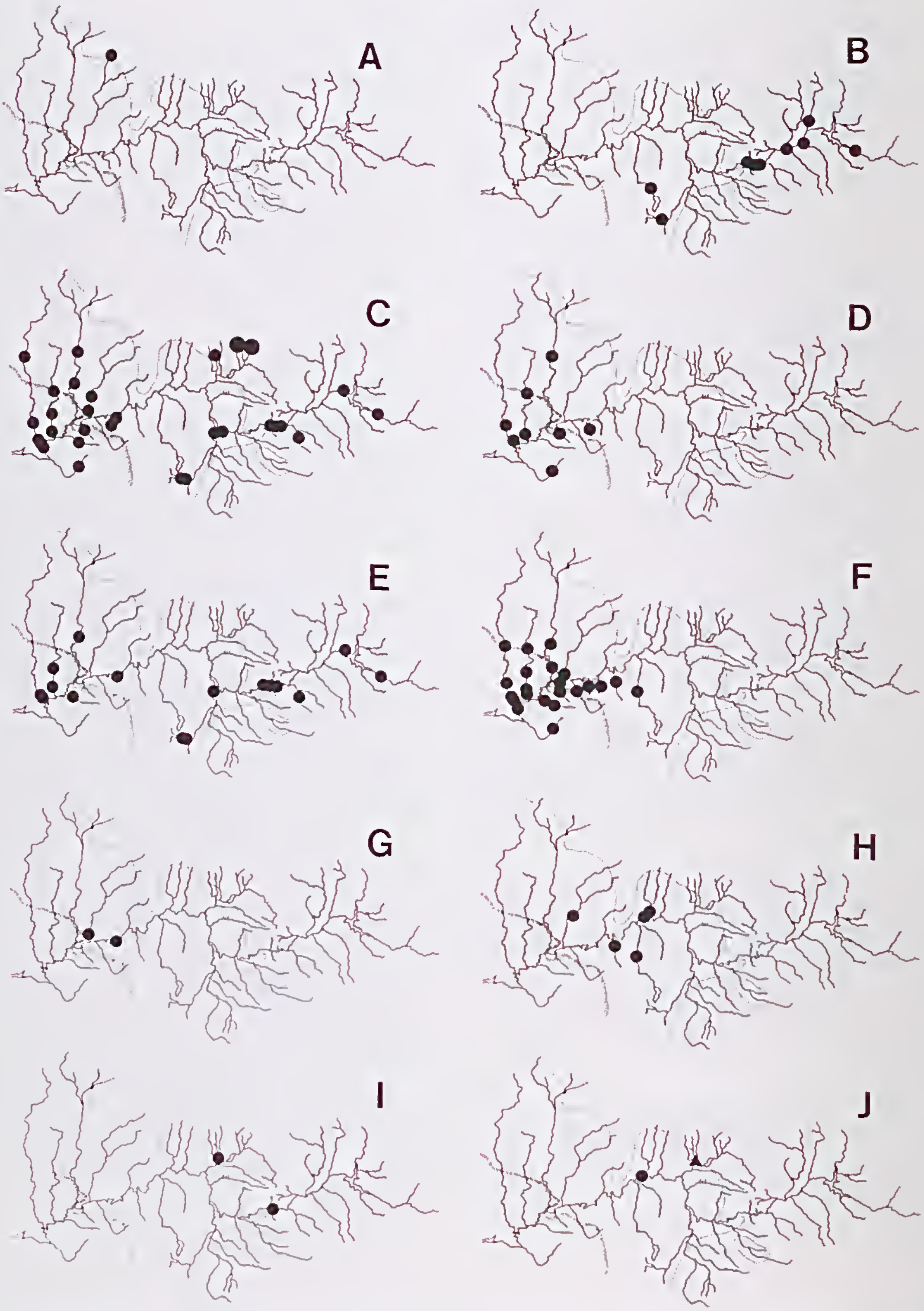


Fig. 12. Distribution of taxa in the Yarra River basin. A, *Chaetophora elegans*. B, *Draparnaldia mutabilis*. C, *Stigeoclonium* (larger dots represent more than one site). D, *S. farctum*. E, *S. tenue*. F, *Cladophora glomerata*. G, *Rhizoclonium hieroglyphicum*. H, *Oedogonium crassum*. I, *O. intermedium*. J, *O.* sp. A (•) and *O.* sp. B, (▲)

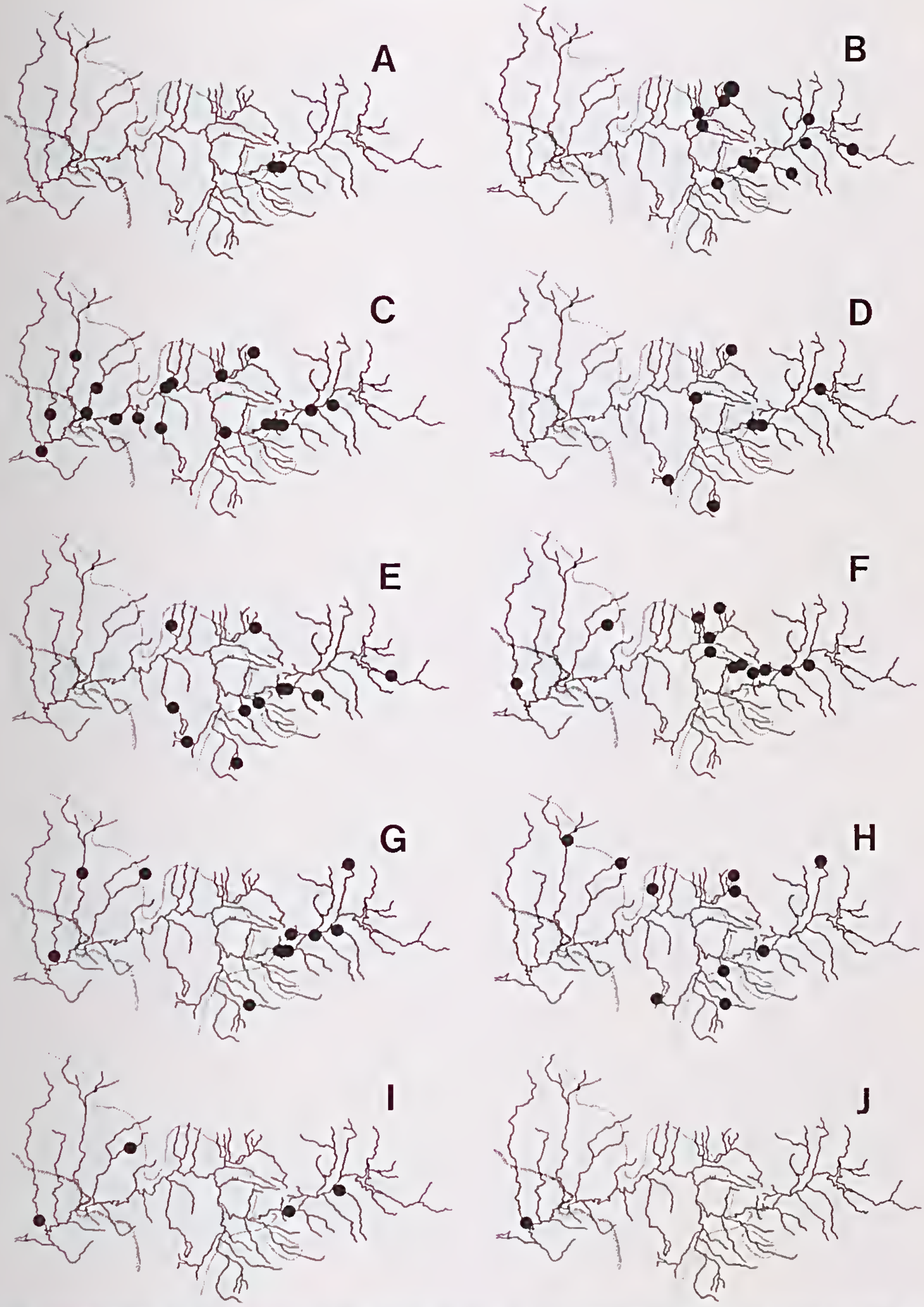


Fig. 13. Distribution of taxa in the Yarra River basin. A, *Oedogonium* (Slender-Filament Group). B, *O.* (Medium-Filament Group). C, *O.* (Broad-Filament Group). D, *Palmellopsis gelatinosa.* E, *Parallela novae-zelandiae.* F, Ulotrichaceae indet. G, *Klebsormidium rivulare.* H, *Microspora floccosa.* I, *Ulothrix subtilis.* J, *Enteromorpha* aff. *prolifera.*

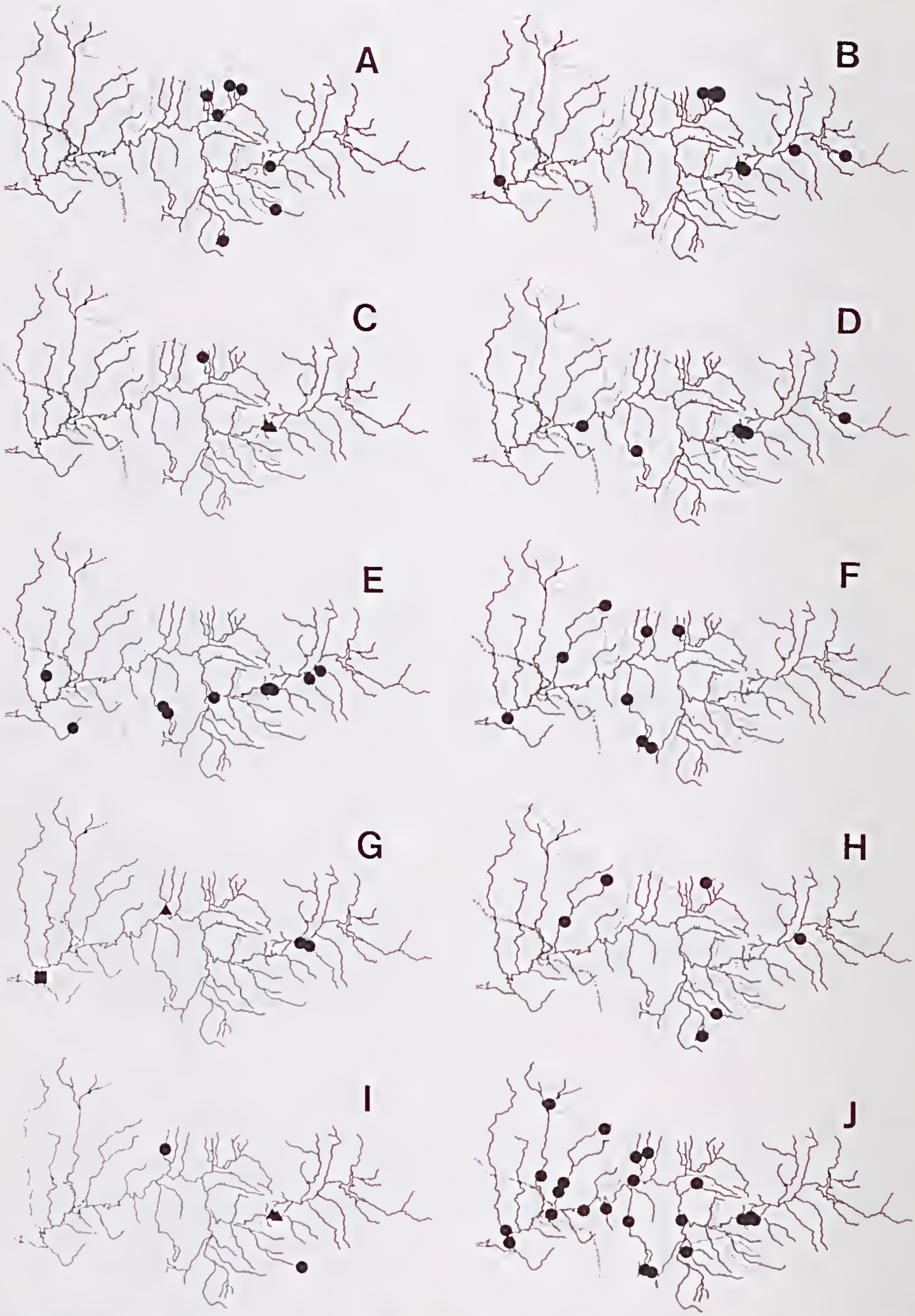


Fig. 14. Distribution of taxa in the Yarra River basin. A, Mougeotioideae (Slender-Filament Group). B, Mougeotioideae (Broad-Filament Group) (large dot represents more than one site). C, *Spirogyra submaxima* (●) and *S. varians* (▲). D, Spirogyroideae (Squat-Cell Group). E, Spirogyroideae (Elongate-Cell Group). F, Spirogyroideae (Medium-Filament Group). G, Spirogyroideae [Replicate-Septum Group (●), Broad Filament Group (▲) and Slender-Filament Group (■)]. H, Zygnemoideae (Vegetative Group). I, *Tetrasporopsis fuscescens* (●) and *Tribonema minus* (▲). J, *Vaucheria*.

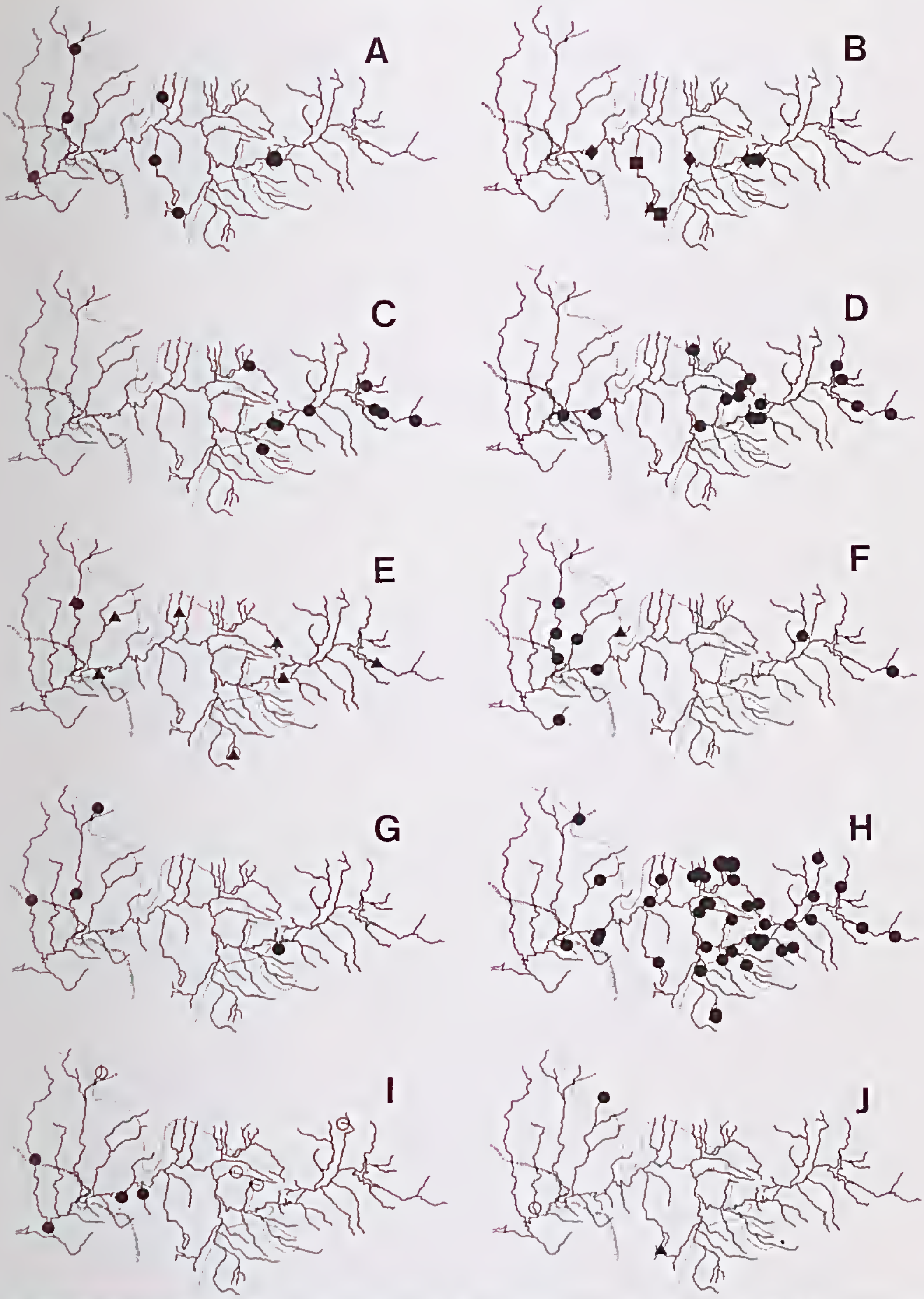


Fig. 15. Distribution of taxa in the Yarra River basin. A, *Vaucheria bursata*. B, *V. aversa* (●), *V. geminata* (▲), *V. prona* (■) and *V. uncinata* (◆). C, *Loefgrenia anomala*. D, *Scytonema hofmannii*. E, *Anabaena oscillarioides* (●) and *Arthrospira jenneri* (▲). F, *Microcoleus vaginatus* (●) and *Porphyrosiphon splendidus* (▲). G, *Schizothrix arenaria*. H, *Schizothrix friesii*. I, *Audouinella hermannii* (●) and probable "Chantransia" stage of Batrachospermaceous life history (○). J, *Batrachospermum atrum* in 1986–1987 (●) and in 1979 (○), and *B. boryanum* (▲).

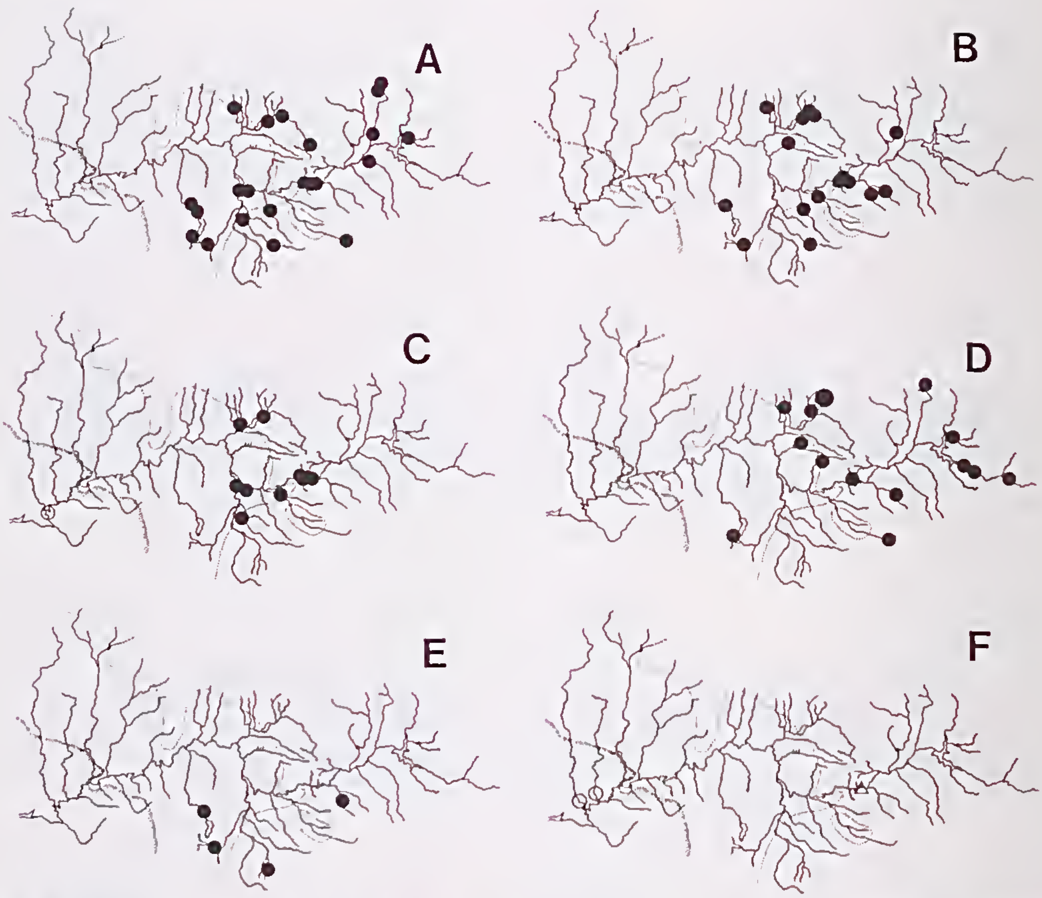


Fig. 16. Distribution of taxa in the Yarra River basin. A, *Batrachospermum gelatinosum*. B, *Nothocladus lindaueri*. C, *N. nodosus*. D, *Batrachospermum keratophytum*. E, *Sirodotia suecica*. F, *Compsopogon coeruleus* in 1980–1981 (○) and *Chroodactylon ornatum* in 1981 (△).

CLASSIFICATION OF STREAM HABITATS IN THE YARRA RIVER BASIN USING MACROALGAE

Biological monitoring of water quality can be used (Pridmore 1983) to (a) identify problem areas; (b) suggest possible chemical and physical effects (and hence those that should be tested); (c) complement chemical and physical analysis (as part of the total budget of the system); and (d) measure the intrinsic effects of the organisms (e.g. as weed species, for food value etc.). Williams (1980: 195) commented that although "no one [taxonomic] group seems pre-eminently suited as a biological monitoring tool, . . . algae have been claimed as particularly useful; unfortunately their taxonomy requires expert training". Williams (1980) further states that the biota of rivers, streams and lakes must be known precisely, both in regard to its taxonomy as well as to its ecology. The distribution and ecology of freshwater algae in Australia, however, have received scant attention.

There is an expansive literature on the attached stream algae overseas (Johansson et al. 1977) but this predominantly concerns microalgae. In Australia, Jolly & Chapman (1966) provided the only detailed account which includes macroalgal ecology in flowing water, from Coxs River in New South Wales. There are incidental ecological notes in some short accounts (e.g. Watts 1883, Hardy 1907, May 1980) and in recent taxonomic treatments of macroalgae (Entwisle & Kraft 1984, Entwisle 1988), but these data are not comprehensive.

The Yarra River basin features in most surveys of freshwater algae in Victoria, but early species records cannot generally be verified

(Entwisle 1989b). One of the major influences on the Yarra River system has been the expansion of urban Melbourne, from the mouth of the river at the time of European settlement (1836) to its current extension into the Upper Yarra Valley. Most early collections from the Yarra River basin came from the downstream tributaries (collections by Bastow in 1899 and Mueller in 1853, both housed in MEL) and from the lower reaches of the river below Heidelberg (Watts 1865, Hardy 1906); however, Berggrens in 1875 (see Nordstedt 1888) and Bastow in 1900 (MEL) made collections in and near the Watts River at Fernshaw. The flora of the Upper Yarra Region has remained mostly unknown.

The results of the current floristic survey have been analysed and compared with water quality data, where available, to provide a classification of stream habitats in the Yarra River basin (see Methods). This classification will provide a reference point for future changes in stream habitats and a means of distilling knowledge about macroalgal communities.

Mueller-Dombois & Ellenberg (1974: 444) stressed that "quantitative field analysis methods and the computer processing methods of vegetation data are . . . really successful only where meaningful qualitative analysis precedes the quantification." In this study, however, quantitative analyses have been used to help distill the data and help towards providing a "meaningful qualitative analysis" (mathematical methods should both simulate and stimulate, according to Clifford & Stephenson 1975: 148). The analyses, therefore, should not be regarded as indicating the ultimate classification of algae and sites, since they are based on preliminary data from a limited number of localities. Using the results of these analyses and experience from field collecting, a system of classification is proposed which can be tested against further information.

Results and Discussion

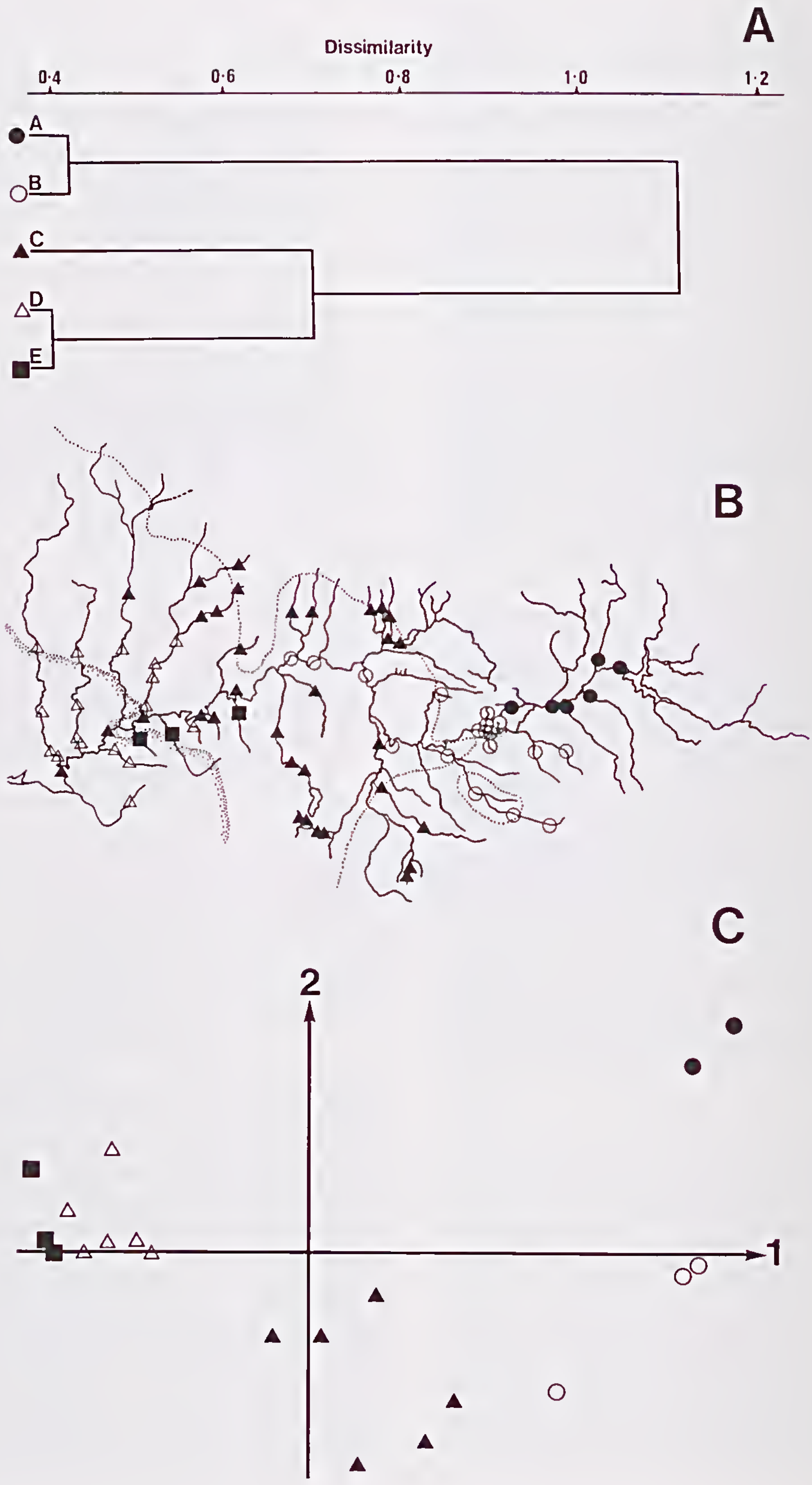
Strata. The results most easily interpreted were achieved by grouping the EPA chemical data with MCAN (Table 5, Fig. 17A, B), and comparing the results with the species data. There is a general trend towards increased eutrophication from group A to group E. In terms of macroalgae, group D is distinguished from group E only in having slightly more sites with *Cladophora glomerata* (100% compared with 89%) and fewer with *Stigeoclonium* spp. (33% compared with 71%). The distinction is dubious, however, when the seasonal variation in dominance of these

Group	Toxicant Mix. 90%	Toxicant Mix. Med	Toxicant Mix. 10%	Total N 90%	Total N Med	Total N 10%	Cond. 10%	Total P 90%	Total P Med	Total P 10%	Temp. 90%	Temp. Med	pH Med	pH 10%	Hard. 10%	Species correlated[1]
A	1.0	0.8	0	0.6	0.5	0.2	21	0.02	0.01	0.01	15.8	11.1	6.4	5.0	1.0	*Draparnaldia*, *Klebsormidium*, Spirogyroideae (Replicate-Septum Group), *Loefgrenia*
B	0.3	0	0	0.8	0.7	0.4	39	0.03	0.03	0.01	16.2	12.5	6.5	5.5	10.3	*Nothocladus* spp., *Batrachospermum gelatinosum*, *B. keratophytum* *
C	0.9	0.5	0	2.1	1.5	0.6	120	0.30	0.14	0.03	16.4	12.5	6.7	5.9	31.5	*Batrachospermum gelatinosum*, *Cladophora*
D	3.2	2.2	0.8	4.1	2.9	0.9	269	1.0	0.59	0.11	20.2	14.1	7.2	6.6	70.1	*Cladophora*, *Stigeoclonium*
E	12.5	6.2	0.4	8.8	5.4	2.2	245	3.1	1.62	0.32	19.7	14.9	7.1	6.5	74.7	*Stigeoclonium*, *Cladophora*

[1] Species listed have CRAMER values greater than 0.5 and are present in more than 20% of sites. They are not ordered by CRAMER or % present values but with most "important" indicator species first (see text).

* Also includes *Draparnaldia*, *Klebsormidium*, *Stigeoclonium*, *Tribonema*, *Palmellopsis*, *Parallela*, *Loefgrenia*, *Oedogonium* (Slender- and Medium-Filament Groups), and Spirogyroideae (Squat- Cell Group).

Table 5. Mean values for important (CRAMER values >0.75) parameters used in MCAN classification of Strata. Data from Victoria, EPA (1982). Units: Toxicant Mixture (Ratio), Total Nitrogen (mg/L), Conductivity (µS/cm), Total Phosphorus (mg/L), Temperature (°C), Hardness (mg/L $CaCO_3$).


A
Dissimilarity
0·4
0·6
0·8
1·0
1·2
A
B
C
D
E
B
C
2
1

species at each site is considered (Entwisle 1989a). Nevertheless, group E seems to be marginally more polluted (in a general sense) than group D, and this trend is paralleled by the greater frequency of *Stigeoclonium* in group E. Whitton (1970a) found *Cladophora glomerata* to be more sensitive than *Stigeoclonium* to zinc, copper and lead, and group E has much higher values for toxicant mixture 90% and median (Table 5).

Group B is richer in species than all other groups and is characterised by Batrachospermaceae. Group C is intermediate between group B and groups D and E in terms of species and chemical composition. Group A is more isolated.

In the Principal Co-Ordinate Analysis (PCOA) of the EPA data (Fig. 17C), the first vector carries 58% of the information, the second vector 11% and the third vector 8%. Strata in groups D and E are very closely packed in the plot of vector 1 versus vector 2 but are only just separated along the first vector. Groups B, C, and the D/E complex are orientated and clearly separated along the first vector, whereas group A is separated from B on the second vector.

The first vector is negatively correlated with pH 10%, total nitrogen 90% and median, temperature 90% and median, hardness 10% and conductivity 10% (–0.83 > corr. coeff. > –0.76). This corresponds to the floral change from species of *Cladophora* and *Stigeoclonium* in polluted strata to species of Batrachospermaceae in 'cleaner' strata. The second vector, which separates groups A and B, is most strongly correlated negatively with temperature 10% and turbidity 10%, and positively with DO 90% and with toxicant mixture 10% and median (±0.37 > corr. coeff. > ±0.25). Strata in group A, therefore, are warmer, more turbid, less oxygenated, and have more toxic metals than those in group B. These factors seem to lessen the dominance of the Batrachospermaceae, although the correlations are very low.

Species most strongly correlated with vector 1 (basically from eutrophic to oligotrophic) are, negatively, *Cladophora glomerata* and, positively, *Klebsormidium rivulare, Draparnaldia mutabilis, Oedogonium* (Medium-Filament Group), *Loefgrenia anomala, Nothocladus* spp. and *Batrachospermum gelatinosum* (±0.85 > corr. coeff. > ±0.5). With vector 2, *Vaucheria bursata, V. prona* and *Sirodotia suecica* are negatively correlated, and Spirogyroideae (Replicate-Septum Group) is positively correlated (±0.52 > corr. coeff. > ±0.45).

The inverse analysis (using NIASM) shows similar trends but slightly different groupings (Fig. 18). The most important (0.95 > CRAMER value > 0.8) chemical parameters (masked from main analysis) are pH 10% and median, hardness 10%, conductivity 10%, non-filterable residues 10%, and temperature median and 90%. Neither nitrogen nor phosphorus are included in the most important correlations with the macroalgal groupings. Most of the significant parameters are generally associated with the distribution of *Cladophora* (Whitton 1970b), which predominates in alkaline, hard waters. Toxic metals can restrict the growth of *Cladophora* but the minimum toxicant mixture level (i.e. 10 percentile) would not be limiting.

The lower Yarra basin (below Yering Gorge), excluding the "northern tributaries", is divided into 3 groups distinguished by the relative abundance of *Stigeoclonium, Cladophora* and *Vaucheria*, and the presence or absence of additional species such as Spirogyroideae spp. and *Oedogonium crassum*. The three upper Yarra and northern tributaries groups are distinguished from each other by the relative abundance of *Stigeoclonium, Parallela*, Batrachospermaceae, *Draparnaldia* and *Vaucheria*. The groups were difficult to characterise precisely on the basis of macroalgae, probably in part due to the heterogeneity of the habitats in each of the strata. In addition, physical parameters such as light intensity, substratum and flow rate are also important in the distribution of macroalgae. To produce a worthwhile classification of macroalgal communities (rather than testing their correlation with chemical gradients), the individual sites were examined.

Sites. The presence/absence data of 56 taxa from 118 sites, many of these sites represented by fewer than 3 taxa, produced only a few interpretable groups using NIASM and MACINF. The higher clusters could not be reconciled with any field observations. Sites with few taxa were often grouped incongruously and, since MACINF matches absences to form the dissimilarity matrix, sites with many taxa were isolated in small groups. The addition of qualitative cover

Fig. 17. A, Dendrogram of selected EPA physical/chemical data (from Victoria, EPA 1983) using MCAN and SAHN (sites were arranged into the strata defined in Victoria, EPA 1983; see Table 1). B, Distribution of the groupings in the Yarra River basin. C, Principal co-ordinate analysis showing first two vectors.

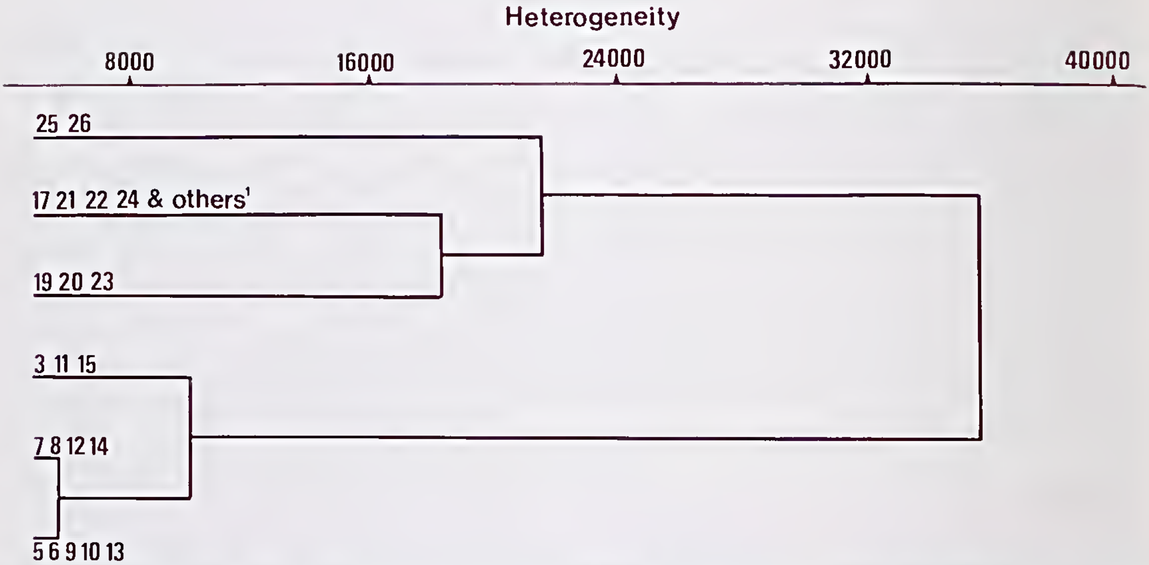


Fig. 18. Dendrogram of sites arranged into strata (see Table 1) and analysed with NIASM; [1]Others = Upper Yarra, Maroondah and Upper Armstrong/O'Shannassy catchments, and Maroondah experimental weirs.

measures for the NIASM analysis did not improve the groupings. These cover measures can also be misleading since most macroalgae are opportunistic and biomass can vary dramatically depending on environmental conditions at the time of sampling.

The classification using the matrix based on the Jaccard measure (MJAC) was better suited to the data (i.e. the groups were interpretable). When sorted with SAHN this classification did not produce a high level of clustering (Fig. 19A) but the enhanced clustering techniques of NIASM and MACINF seemed to obscure real grouping anyway. The dendrogram of the MJAC/SAHN classification was subjectively terminated at the 11 group level (Fig. 19A, B). (Note that Clifford & Stephenson 1975 stressed that different cut-off points can be used on the one dendrogram but it was not necessary or advantageous to do that here.)

The inverse analysis of species with sites as attributes using MSED/SAHN resulted in few useful species groupings (see Appendix for twoway table based on MSED/SAHN species classification and MJAC/SAHN site classification). Some of these species groups can be used to distinguish ecologically similar sites, while in other cases subjectively selecting species from a few groups is better. In general, the first two species groups are found in oligotrophic, acidic, mountain streams and rivers; *Vaucheria* in slightly polluted, alkaline streams; *Cladophora* in heavily polluted urban streams; and *Stigeoclonium* in both disturbed mountain streams and polluted urban streams. These subdivisions correspond closely to the termination of the SAHN dendrogram at the 13 group level. The resultant communities are artificial clumpings of what appears to be a complex overlapping of species distributions, but they aid in condensing the information.

The communities described below are named on the basis of the most distinctive species found at the group of sites. The species do not usually occur solely in that community, nor are they found in all constituent sites. The temperature range is derived from measurements taken at the time of sampling and so is likely to be narrower than the real range (the *Cladophora/Stigeoclonium* and *Nothocladus* Communities occur at sites which were more intensively studied and are likely to have a more realistic temperature range). The species frequency is the average number of species found per site.

Fig. 19. A, Dendrogram of sites using MJAC and SAHN communities: *Cladophora/Stigeoclonium* (●), *Cladophora* (▲), *Vaucheria* (■), *Stigeoclonium* (▼), Mixture (♦), *Batrachospermum keratophytum* (○), *Scytonema/Klebsormidium* (△), *Nothocladus* (□), *Oedogonium* (Medium-Filament Group) (▽), *Schizothrix friesii* (◇), no macroalgae (×). B, Distribution of these groups in the Yarra River basin.


A
Dissimilarity
2·0
3·0
4·0
X
B

The communities are described in approximate order from those occurring in polluted habitats to those in pristine habitats.

Cladophora/Stigeoclonium *Community*

Sites 1, 2, 12, 13, 23, 55, 56, 57, 59, 84, 86, 87.

Species frequency: 2.8; water temperature range: 7–25°C.

Polluted, lowland (altitude less than 150m), urban creeks are dominated by *Cladophora glomerata* in summer and *Stigeoclonium* spp. in winter (Entwisle 1989a). The water is alkaline and hard (Victoria, EPA 1982) and, in January 1988 (sites 12, 13, 55 measured twice in consecutive weeks), pH ranged from 7.7–8.0 and conductivity from 630–2160 μS/cm (site 13, however, only ranged from 630–930 μS/cm). Few other species grow in these habitats. *Klebsormidium rivulare* may be present in winter, on exposed rocks or just submerged. The red alga *Compsopogon coeruleus* was found extensively in Darebin and Merri Creeks in 1981 (Entwisle & Kraft 1984) but was not found in 1986–87 during the current study.

This community is also found in urban catchments outside of metropolitan Melbourne (e.g. Yarrawee and Latrobe Rivers).

Cladophora *Community*

Sites 10, 11, 58, 85, 89, 90, 91, 98, 100, 118.

Species frequency: 3.4; water temperature range: 12–20°C.

Although similar to the *Cladophora/Stigeoclonium* community, most of these sites have no *Stigeoclonium* spp. A number of additional distinctive species are present, however, namely *Audouinella hermannii* and *Vaucheria* spp. All sites occur in the lower reaches of the Yarra River where there is reasonably heavy urban pollution. *Stigeoclonium* spp. can generally tolerate higher levels of organic and metal pollutants (Blum 1957, McLean 1974) than *Cladophora* and thrive in heavily polluted streams, but in the Yarra River basin they also grow in more oligotrophic waters than *Cladophora*. Undoubtedly there exists a gradient of eutrophication in polluted sites, and the *Cladophora/Stigeoclonium* and *Cladophora* communities include habitats from opposite ends of this gradient as well as intermediate sites. The lower Yarra River (sites 98, 100), for example, has lower nutrients than the urban tributaries flowing into it (Victoria, EPA 1983). *Cladophora* can grow in water with low nutrients, but high pH or "hardness" is generally required (Marker & Close 1982).

In other catchments, there are similar gradients from the *Cladophora/Stigeoclonium* community to a more species rich flora. In the Yarrawee River, for example, the high nitrogen and phosphorus loading of the Ballarat Sewage Plant effluent (and probably some farmland runoff) allows *Cladophora* and *Stigeoclonium* to dominate the river. About 25 km from this input, however, Spirogyroideae (Elongate-Cell Group) becomes a co-dominant, and other genera (e.g. *Palmellopsis*) are found in small quantities.

Vaucheria *Community*

Sites 3, 4, 7, 9, 15, 17, 22, 37, 42, 43, 96, 101.

Species frequency: 3.8; water temperature range: 10–14°C.

Vaucheria, usually *V. bursata*, grows in slow-flowing parts of streams. Although it is found on muddy riverbanks throughout the catchment, it is seldom truly aquatic (Entwisle 1988). Most sites seem to have some nutrient input, but agricultural rather than industrial or urban runoff. Various species grow with *Vaucheria*, Spirogyroideae (Medium-Filament Group) and *Stigeoclonium* spp. being the most common.

Stigeoclonium *Community*

Sites 29, 61, 80, 103, 104, 107, 108, 109, 111, 112, 114.

Species frequency: 2.1; water temperature range: 9–14°C.

Upland streams (altitude greater than 300 m) with some disturbance are often dominated by *Stigeoclonium* spp. Few other species are found in these sites, but those that are, e.g. *Nothocladus lindaueri, Batrachospermum keratophytum, Sirodotia suecica* and Mougeotioideae spp., are typical of oligotrophic waters. Most of the sites in this group are small experimental weirs in the Maroondah catchment. The water at these sites is acidic and of fairly high quality (pH 5.9–6.7 and EC 73–111 μS/cm at sites 103, 104, 107-109, 111, 112, 114 in March 1988), even following experimental logging in catchments (Langford & O'Shaughnessy 1977), but the concrete substratum is swept weekly with a broom and the sediment on the weir disturbed. The algae are probably distributed on brooms and the boots of personnel.

Biggs & Price (1987) found *Stigeoclonium* to be typical of low conductive streams similar to the habitats included in this and the following community. Measurements taken at sites 107 and 116 showed relatively low levels of Ca (5.4–7.2 mg/L) and Mg (0.6 mg/L).

Scytonema hofmannii/Klebsormidium rivulare *Community*

Sites 65, 71, 73, 34, 36, 45, 47, 69, 70

Species frequency: 2.3; water temperature range: 6–14°C.

Few species other than *S. hofmannii* and *K. rivulare* were found at these sites (Ulotrichaceae indet. has been omitted since many records may refer to *Klebsormidium* anyway). Some additional species were typical of slightly eutrophic water, e.g. *Vaucheria* spp., and others of oligotrophic mountain streams, e.g. *Nothocladus lindaueri* and *Batrachospermum keratophytum*. The widespread *Schizothrix friesii* was found in half the sites. All sites were in upland creeks and rivers (altitude greater than 600 m), most of which flow through naturally forested land. This community is closely related to the *B. keratophytum* and *Nothocladus* Communities, and the separation of these three communities on ecological grounds requires further study.

Schizothrix friesii *Community*

Sites 30, 33, 49, 77, 92.

Species frequency: 1.8; water temperature range: 10–15°C.

This community is representative of species-poor sites in warmer, little shaded creeks. The dominant species is *S. friesii*, with either *Draparnaldia mutabilis*, *Palmellopsis gelatinosa* or *Loefgrenia anomala*. *S. friesii* is found throughout the Yarra River basin and cannot be characterised ecologically (it may include a number of ecophenes). These sites may be individualistic; Coranderrk Creek at Healesville (Site 33), for example, had an extensive bloom of *P. gelatinosa*, a species found in only small quantities elsewhere (except occasionally in the *Nothocladus* Community).

Oedogonium *(Medium-Filament Group) Community*

Sites 67, 75, 81, 82, 113, 116.

Species frequency: 2.7; water temperature range: 9–12°C.

Oedogonium (Medium-Filament Group) is the only taxon found in all sites in this group but other species, e.g. *Batrachospermum keratophytum*, *Nothocladus lindaueri* and *Parallela novae-zelandiae*, are typical of these oligotrophic mountain streams. This community has close species affinities with the *Nothocladus* Community but is poorer in species and seems to be restricted to smaller shaded streams in upland areas (altitude greater than 300 m).

Nothocladus *Community*

Sites 16, 18, 19, 20, 21, 24, 25, 26, 28, 39, 44, 52, 72, 74, 76, 78, 83, 88.

Species frequency: 7.5; water temperature range: 6–19°C.

The sites dominated by *Nothocladus nodosus*, *N. lindaueri* and *Batrachospermum gelatinosum* are generally species rich. They occur in the larger creeks and rivers, generally where the canopy has been opened up. There is usually some nutrient input but water quality is generally fairly high (Victoria, EPA 1983). The Yarra River at Warrandyte (Site 16) has none of the dominant species and represents the more polluted extent of this community. It is a site intermediate between the lower and upper reaches of the Yarra River (see below). Sites 26, 28, 78, 83, 88 (measured January 1988) have 11.4–21.0 mg/L Ca and 0.6–1.2 mg/L Mg, pH ranging from 6.4 (site 26) to 8.0 (site 83), and conductivity from 82 μS/cm (site 78) to 109 μS/cm (site 28).

Batrachospermum keratophytum *Community*

Sites 14, 40, 53, 60, 63, 64, 66, 68, 105.

Species frequency: 3.3; water temperature range: 6–12°C.

Many of the upland (altitude mostly greater than 600 m), shaded, cool-water creeks are dominated by *B. keratophytum*. *Batrachospermum gelatinosum*, *Scytonema hofmannii* and *Loefgrenia anomala* are also common. Most of these sites have been little disturbed.

Other communities

Sites 8, 27, 31, 32, 38, 41, 46, 48, 50, 51, 54, 62, 79, 106, 115, 117.

Species frequency: 3.8; water temperature range 7–19°C.

There are no suitable distinguishing species for these sites which include a wide range of species and habitats. Mougeotioideae spp., *Oedogonium* spp., *Klebsormidium rivulare* and *Draparnaldia mutabilis* are the most common species found. Most sites are in naturally forested areas, although the Plenty River at Mernda (site 32) and Dixons Creek at Yarra Glen (site 48) are exceptions.

Running Creek, Kinglake National Park (site 117) is an interesting site in that it represents one of the few northern tributaries that are little disturbed. The EPA (pers. comm.) found that $CaCO_3$ was high (570–730 mg/L) downstream of the collection site. This is contrary to most tributaries in forested areas, where the water is much softer. At site 117, however, calcium and magnesium levels were not particularly high (Ca 8.0 mg/L, Mg 1.2 mg/L). The species recorded, *Batrachospermum atrum* and *Chaetophora elegans*, are generally indicative of hard water overseas (Israelson 1942, Blum 1957). In January 1988 the pH was 6.3 and the EC was 157 µS/cm, the latter figure being relatively high for the upper parts of the catchment.

Sites with *Batrachospermum gelatinosum* and *Nothocladus* spp. (sites 46, 51, 62, 79, 106) may be better included in the *Nothocladus* or *B. keratophytum* Communities. Starvation Creek (site 31) had extensive growths of Spirogyroideae (Elongate-Cell Group) in winter, similar to those found in McMahons Creek. The latter is included in the *Nothocladus* Community because it had a far greater range of species in summer. Both streams have upstream disturbances caused by forestry and water diversion. As with all sites in this "community", further work is needed to classify them adequately.

No macroalgae

Sites 5, 6, 93, 94, 95, 97, 99, 102, 110.

Water temperature range: 9–14°C.

These sites are mainly in large, turbid stretches of the Yarra River with no suitable substrata for macroalgae, or in small intermittent streams. It is probable that minimal growth of macroalgae would be found in such sites even under the right conditions. Many small tributaries in forests with a dense canopy also support little or no macroalgae but few of these sites were sampled.

Yarra River gradient

The relationship between species distributions and eutrophication levels in the Yarra River itself reflect the trends in the catchment as a whole. The important changes in species composition in the Yarra River are given in Table 6. Sites 100, 98 and 96 are in the eutrophic group of sites described above; sites 16, 25, 83, 78, 26, 27 and 62 are intermediate; and sites 60 and 63 are in the oligotrophic group.

Cladophora is almost restricted to areas of urban pollution (although it was also found in the Plenty River at Morang South, site 91) where it usually grows in association with *Stigeoclonium*. There is a transitional area at Lower Plenty (site 98) where *Scytonema hofmannii* and *Cladophora* are found. There is another transitional

Site:	100	98	16	96	25	83	78	26	27	62	60	63
Cladophora	—	—										
Audouinella	—	—	—*									
Stigeoclonium	—	—	—	—	—	—	—	—				
Scytonema hofmannii		—	—	—	—	—	—	—	—	—	—	—*
Schizothrix friesii			—	—	—	—	—	—	—	—	—	—*
Batrachospermaceae					—	—	—	—	—	—	—	—*
Loefgrenia					—	—	—	—	—	—	—	—*
Draparnaldia						—	—	—	—	—		
NH_3:	0.22	0.07	0.6	0.03	0.02				0.01			
NO_3:	0.83	0.58	0.54	0.39	0.23				0.09			
P:	0.26	0.18	0.16	0.07	0.09				0.05			

* Although missing at one or two sites, it is presumed that intensive collection would show the presence of the species throughout the range given. *Audouinella* was not found between sites 100 and 16 (Dights Falls and Warrandyte respectively) in this study but has previously been found in the Yarra River at Eltham.

Table 6. Variation in species composition in riffle sites on Yarra River from Dights Falls (site 100) to Upper Yarra catchment (sites 62, 60, 63). Chemical data in mg/L, from MMBW in Campbell et al. 1982.

area near Warburton (sites 25, 83, 78, 26) where Batrachospermaceae and *Loefgrenia* first appear but *Stigeoclonium* is also present. Nutrient levels here are apparently high enough to support some pollution-tolerant algae but not so high as to inhibit clean-water species (if the latter are in fact inhibited by high nutrient levels rather than by competition from other species or by sensitivy to metals, etc.). Although predominant in pristine mountain creeks, *Scytonema hofmannii* occurs almost throughout the freshwater parts of the Yarra River.

Overseas studies

In both Europe and North America most streams seem to support genera similar to those in the Yarra River basin, and light, temperature, pH/hardness and eutrophication are everwhere important limiting factors for macroalgae. Most of the overseas studies on macroalgal ecology are from higher latitudes than the Yarra River, so that temperatures are lower and snow and snowmelts are important factors. Many northern hemisphere catchments also have "harder", more alkaline natural waters.

Israelson (1942, 1949) proposed the first ecological classification of streams based solely on macroalgae. He divided the streams of Scandinavia into the "*Vaucheria* Type" in eutrophic waters, and the "*Zygnema* Type" in oligotrophic waters. Whilst this division is apparent in the present analyses of both sites and strata, there are also habitats in the Yarra River basin that are obviously intermediate. The most eutrophic portions of streams in the Yarra River basin are dominated by *Cladophora, Stigeoclonium* and *Vaucheria*. The oligotrophic sites are dominated by *Nothocladus* spp., *Batrachospermum gelatinosum, B. keratophytum, Loefgrenia anomala* and *Scytonema hofmannii*. As in the Scandinavian streams, the last group of sites can be subdivided into those with Batrachospermaceae and those without. There are also sites in the Yarra River basin which include species from both of these groups. Other sites, apparently intermediate in terms of eutrophication, are dominated by *Palmellopsis* or *Schizothrix friesii*.

There are other minor differences between the findings of Israelson (1949) and those of the present study. Israelson included *Draparnaldia* in the *Vaucheria*/eutrophic type, but in the Yarra River basin *Draparnaldia* is often found with Batrachospermaceae in sites of an intermediate nature. *Batrachospermum boryanum* is also included in this intermediate group of sites in the Yarra River basin. Zygnemataceae in the Yarra River basin do not seem to be sufficiently common or sufficiently restricted in distribution to be used for classification, although the intermediate sites are notable for their greater number of Zygnemataceae species. Environmental factors other than those measured or estimated may be linked with the distribution of this group of algae.

Johansson (1982) characterised certain stream types in Sweden by macroalgae. Of the species occurring commonly in the Yarra River basin, Johansson mentioned *Cladophora glomerata* and *Vaucheria* spp. in low altitude streams with high pH, conductivity and calcium; *Batrachospermum gelatinosum* (= *B. moniliforme* of Johansson) in shaded, lowland streams with brown water; and *B. gelatinosum* and *Vaucheria* spp. in small cold streams. Various Zygnemataceae were also associated with these species. In the Yarra River basin Johansson's first two groups occur in similar habitats but the third group is more typical of larger intermediate streams. In the small, cold streams running into the Yarra River, *Batrachospermum keratophytum* and *Scytonema hofmannii* are most common. Johansson found an *Anomoeonsis-Tolypothrix* community in similar high altitude streams (*Tolypothrix* is a cyanophyte referred to *Scytonema* by Drouet 1973). There is no apparent reason (such as high nitrate levels) for the predominance of a non-heterocyst ecophene of *Scytonema hofmannii* in the oligotrophic parts of the Yarra River basin. As in the present study, vegetative groups of *Oedogonium* were found by Johansson to occur in many habitats and proved to be of little value in classification.

In Alaska, temperate/sub-arctic streams at a similar latitude to those in Scandinavia are dominated by *Hydrurus foetidus* (Villars) Trevisan or *Phormidium retzii* (C. Agardh) Gomont, depending on stream size and temperature (Sheath et al. 1986b). In more temperate regions of North America *Hydrurus* is less important, but there is generally a dominant cyanophyte in at least some streams. The Saline River of the United States, intensively studied by Blum (1957), is primarily alkaline and calcareous (as are the streams studied by Johansson), and the *Phormidium–Schizothrix–Audouinella* community is distinctive in unpolluted portions (the *Schizothrix* mentioned by Blum 1957 is tufty like *Scytonema hofmannii*).

Several of the stream communities recognised by Dillard (1969) in North Carolina are found in the Yarra River basin. The "*Spirogyra/Oedogonium* community" found in spring/summer is common in the intermediate and some oligotrophic streams in well-lit riffles. The "*Phormidium* Aufwuchs" found in spring may be equivalent to the mats of *Schizothrix friesii* so common in the Yarra River basin. Dillard found that these mats are replaced by *Batrachospermum sirodotii* in early summer. In the Yarra River basin, *B. gelatinosum* and *Nothocladus* spp. are dominant in the warmer months. "*Vaucheria* Aufwuchs" were found in slower parts of rivers in North Carolina, as they were in the Yarra River. These and most of the other communities mentioned by Dillard (1969) are typical of the intermediate stretches of the Yarra River basin.

Most of the macroalgal genera found in the softwater, acid streams of Rhode Island (Sheath et al. 1986a, Sheath & Burkholder 1985) also occur in the Yarra River basin. The pH (effecting the carbon dioxide/carbonate balance) was considered by Sheath & Burkholder (1985) to be a key influence on algal distribution. Seasonal abundance was related to irradiance, primarily due to the development of a canopy over the stream. In the mountain streams of the Yarra River basin the canopy is largely evergreen, and seasonal effects seem to be due mostly to temperature rather than irradiance or photoperiod.

The groupings of New Zealand streams by Biggs & Price (1987) separate the polluted stretches dominated by *Cladophora glomerata* from the less eutrophic stretches dominated by other green algal genera such as *Ulothrix*, *Spirogyra* and *Stigeoclonium*. Few red algae were recorded, perhaps because they did not form the large proliferations that were the topic of Biggs & Price's paper.

Value of ecological groupings.

As with all stream organisms, the ecology of macroalgae seems to differ from that of neighbouring terrestrial inhabitants. In most cases there is little value in talking of succession or climaxes; competition for substratum and space does occur but there is no unidirectional change in the composition of the flora. It seems better to talk of something like a "latent flora" which provides the basis for the flora observed at any one time and in any one micro-habitat. Environmental factors effect the composition of this "latent flora" and also the extend to which it is expressed as visible biomass. Many macroalgae are maintained through seasons not suitable for growth by small patches of filaments and/or spores. The complex interaction of chemical and physical parameters in a stream leads to a visibly expressed flora which is stochastic in any practical sense: floods, in particular, play a very important role in the amount of biomass produced (Tett et al. 1978; Tominga & Ichimura 1966).

It should be possible, however, to predict a *likely* or *probable* flora in most stretches of any given river. That is, at some places in a particular river habitat, certain species are more likely to be growing at certain times of the year or following certain events than other species. The converse is also true: the presence of certain species in some quantity can suggest certain probable environmental events or parameters. At our present level of understanding of the Yarra River system, such predictions are only possible in very uniform environments such as the polluted urban creeks.

CONCLUSIONS

The Yarra River basin includes mostly clean, acidic streams which become more polluted (nutrient rich, harder and more alkaline) as they flow through or meet streams from agricultural and urban regions. Even in the most polluted reaches, *Cladophora glomerata*, a species not tolerant of high metal pollution, is found. *Stigeoclonium* spp. are common in strongly or mildly enriched streams but not in large masses, except in urban creeks in winter. In the acidic, shaded, clear streams few species are found but the Batrachospermaceae usually appear when the canopy is not too dense. Associated with the Batrachospermaceae are *Scytonema hofmannii*, *Loefgrenia anomala*, and *Parallela novae-zelandiae*.

Mountain streams with some nutrient input may be dominated seasonally by *Spirogyra* (autumn/winter) or, more rarely, by *Palmellopsis* (spring/autumn). *Vaucheria* occurs both in sites with intermediate levels of eutrophication, together with Batrachospermaceae and other "clean-water" species, and in small agriculturally polluted creeks. *Oedogonium* (Medium-Filament Group) and *Draparnaldia* are also taxa which occur commonly in intermediate to clean stretches of river. Species richness is greatest in intermediate, broad stretches of the Yarra River and minimal in polluted urban streams and pristine mountain streams. This trend is paralleled in studies of physically disturbed environments, where species richness is higher after "intermediate" disturbance (Connell 1978). The phenology and distribution of macroalgae in the species-rich stretches of the Yarra River near Warburton and the species-poor creeks in the upper part of the catchment are presently under examination.

There are many avenues for further study into the ecology of freshwater macroalgae in Australian streams; e.g. an analysis of the limits of *Stigeoclonium* distribution; the phenology of macroalgae in pristine mountain streams with *Scytonema hofmannii*, and their tolerance to disturbance; the distribution and autecology of *S. friesii* (which may contain a number of ecophenes); intensive study of the life histories and distributions of *Nothocladus* species and *Batrachospermum keratophytum*; and studies into the more restricted taxa (such as *B. boryanum* and species of *Sirodotia*, *Porphyrosiphon*, *Arthrospira* and *Audouinella*) to determine if and why they are limited to certain areas. In addition, there is great potential for extensive comparisons between the Yarra River basin and other Victorian basins that are exposed to different sorts of influences (e.g. Acheron and Latrobe Rivers).

The water quality objectives for the Yarra River system include the absence of "excessive or nuisance growth of aquatic plants" (State Environmental Protection Policy, W-29). Such growths occur in urban creeks in summer and in some altered mountain streams (such as Starvation and McMahons Creeks) in autumn and winter. In both cases the algal growths could restrict some of the beneficial uses of streams, such as fishing, recreation and ecosystem protection. In most other areas macroalgae do not presently form "nuisance" growths.

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Appendix. Twoway Table showing site and species groups discussed in text. Presence (+) or absence is indicated rather than abundance because the total biomass present at the time of collection depends on a combination of the recent flood history and a number of seasonal factors.

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Community                  No-Macro- Stigeo-     Cladophora/  Vaucheria    Cladophora Batr.     Scytonema/ Nothocladus         Other (Mixed)     Schiz. Oedog.
                           Algae     clonium     Stigeoclonium                        kerat.    Klebsor.                                        fries. (Med.)
                                  11    11111111                         1         11         1                                  1   1        1            11
Site Number                  9999901 26800000111   1125555888     11234490 1815899901 145666660 6773334467 111222222345777788  551 351233444670 33479 678811
                           563457920 91034789124 122335679467 347957272361 0518901808 403034685 5134565790 689014568942246838  0458817712168296 03972 751236

Scytonema hofmannii                                                               +      +++    ++++  +  + +     ++       ++
Batrachosp. keratophytum                 +                                            +++++++++    +  +           +                         +++         +  +
Oedogonium (Medium.)                  +                                                                           ++  +                   +  ++       ++++++
Batrachosp. gelatinosum                                                               +++  +                ++++++++++++++++        +
Nothocladus lindaueri                  +                                                    +           +   +  +  +  ++ ++ ++       +        +         +
Klebsormidium rivulare                                          +  +                                          ++++++        ++      ++      +++ + +
Mougeotioideae (Slend.)                    +                                                          ++          +            +++
Ulotrichaceae sp.                          +                     +                                 +++++++         +
Vaucheria bursata                                                +  ++++  +       +                         +               +
Vaucheria sp.                                                 ++++++++++++   + + +++                        +  +   +        +
Schizothrix friesii                    ++     ++          ++   +       ++                ++   + ++   ++ +  + ++  ++++ +++ +++  + +              +++++ + ++ +
Cladophora glomerata                                 ++++++++++++               +++++++++
Stigeoclonium tenue                   +++++++++++      ++    +   +   +                                      +   +          ++
Stigeoclonium spp.                    +++++++++++ ++++++++++++ + +   +         +  + +                       +   ++++       ++
No visible Macroalgae      +++++++++
Oedogonium (Broad.)                                    +       +   +    +      +   +   +                   +     ++       ++          + + ++  +
Draparnaldia mutabilis                                                                                       + +  ++      +           +     ++  +
Palmellopsis gelatinosa                                                                                        + ++        +                  +  ++
Parallela novae-zeland.                                                       +                  +                  +  +  +   + + + +  +                        +
Spirogyroideae (Squat.)                                                                                     ++     +       ++                ++
Spirogyroideae (Elong.)                                     +                                                      ++   +++      ++           +
Loefgrenia anomala                                                                       +++                      +     + ++          +     +       +
Nothocladus nodosus                                                                                                   + +++      ++++             +  +
Spirogyroideae (Replic.)                                                                                                                      ++
Arthrospira jenneri                                                                 ++                                 +    +            +   +
Stigeoclonium farctum                                     +++  ++++                                                     + +
Chaetophora elegans                                                                                                                              +
Rhizoclonium hieroglyph.                                  +                                                        +
Oedogonium crassum                                                             +   +    +      +                                                           +
Oedogonium intermedium                                                                                                                                  +
Oedogonium sp. A                                                                        +
Oedogonium (Slender.)                                                                                                                  +       +
Tetrasporopsis gelat.                                                            +                 +
Microspora floccosa                                                            +     +  +            +                           +   + +        +  +
Ulothrix subtilis                                                               +           +                                    ++
Mougeotioideae (Broad.)                   + +                                    +                                    ++                 +      +++
Spirogyra submaxima                                                                                                                   +
Spirogyra varians                                                                                                                                + +
Spirogyroideae (Slend.)                                                                     +
Spirogyroideae (Medium.)                                               ++  +   +           +  +                        +     +
Spirogyroideae (Broad.)                                                                                                                                 +
Zygnemoideae                                                         +                                                                  +           +  + ++
Tribonema minus                                                                                                                   +        +
Vaucheria geminata                                                              +
Vaucheria prona                                                                     ++
Vaucheria uncinata                                                                                                                         +
Anabaena oscillarioides                                                                                                                          +
Microcoleus vaginatus                                           +                           +  +     + +              +                            +
Porphyrosiphon splendens                                               +                                                                         +
Schizothrix arenaria                                                                      +  +                                                                       +
Audouinella hermannii                                                                    ++   +                       +        +
Oedogonium sp. B                                                                                                                                          +
Batrachosp. boryanum                                                          +
Sirodotia suecica                                 +                                                                     + +               +
Batrachosp. atrum                                                                                                                                   +
Enteromorpha prolifera                                        +
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